NASA Technical Memorandum TM 107550

(NASA-TM-107550) DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS FOR SHUTTLE MISSION STS-50 (NASA) 148 p

N92-33703

Unclas

G3/16 0118075

Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-50

August 1992

National Aeronautics and
Space Administration

NASA Technical Memorandum TM 107550

Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-50

Gregory N. Katnik
NASA/Kennedy Space Center

Scott A. Higginbotham
NASA/Kennedy Space Center

J. Bradley Davis
NASA/Kennedy Space Center

August 1992

National Aeronautics and
Space Administration

DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-50

June 25, 1992

Prepared By:

Scott A. Higginbotham
Scott A. Higginbotham
NASA/Kennedy Space Center
TV-MSD-22

J. Bradley Davis
J. Bradley Davis
NASA/Kennedy Space Center
TV-MSD-22

Approved:

Gregory N. Katnik
Gregory N. Katnik
Lead, Ice/Debris/Photo Analysis
NASA/Kennedy Space Center
TV-MSD-22

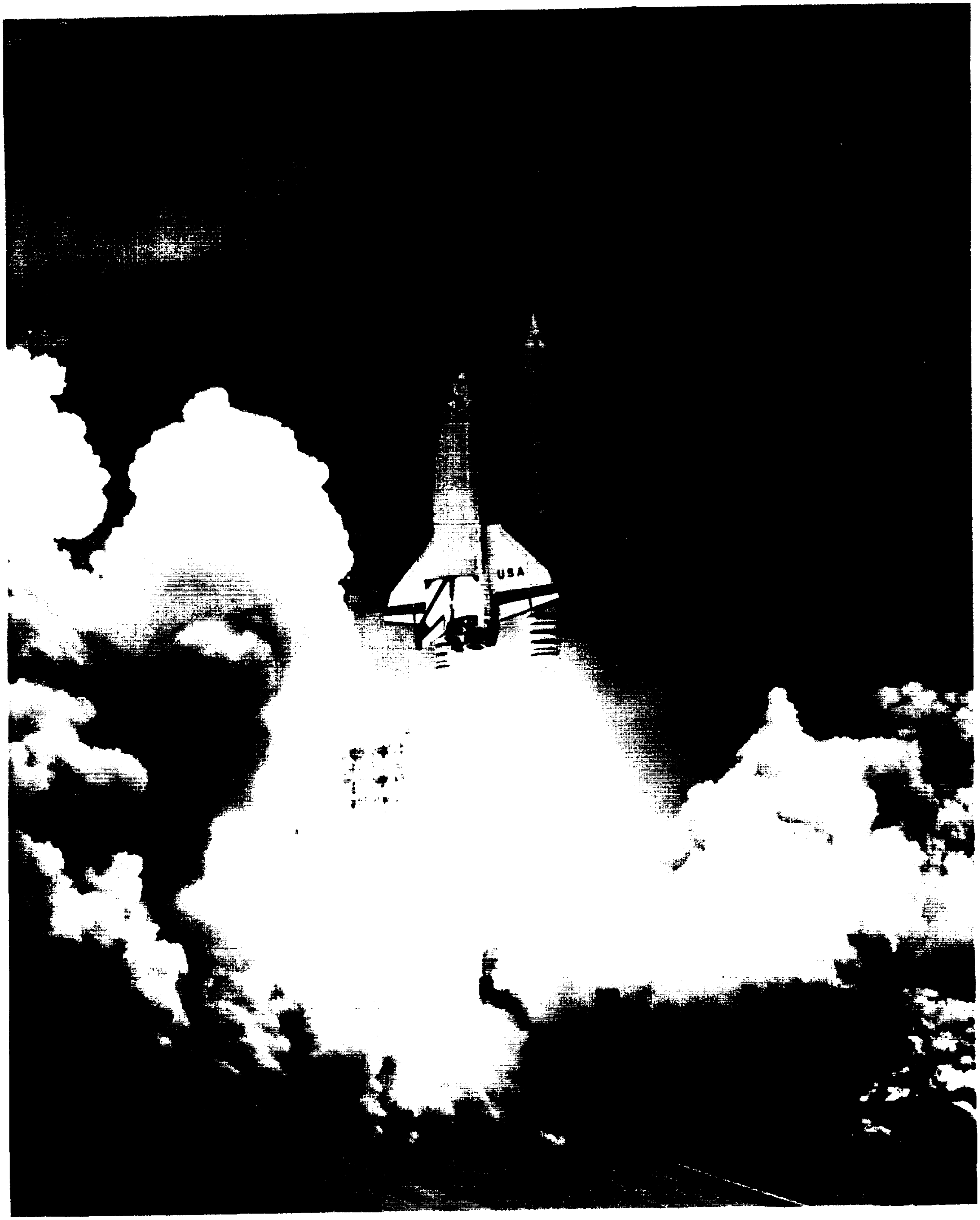
Pedro J. Rosado
Pedro J. Rosado
Chief, ET Mechanical Sys
NASA/Kennedy Space Center
TV-MSD-22

TABLE OF CONTENTS

FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center (KSC) Photo/Video Analysis, reports from Johnson Space Center, Marshall Space Flight Center, and Rockwell International - Downey are also included in this document to provide an integrated assessment of the mission.



Shuttle Mission STS-50 was launched at 12:12 p.m. local 6/25/92

1.0 Summary

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 24 June 1992. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (12th flight), ET-50 (LWT 43), and BI-051 SRB's. There were no vehicle or facility anomalies.

The vehicle was cryoloaded for flight on 25 June 1992. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice or frost conditions outside of the established data base. The External Tank TPS acreage was covered by light condensate. The LH2 ET/ORB umbilical leak sensor detected no significant hydrogen during the cryoload. A 10" x 0.25" crack occurred in the forward surface of the -Y ET/SRB vertical strut cable tray near the longeron closeout interface. The crack exhibited no offset and contained no ice/frost. The crack occurred in an area where the stress relief cut had been eliminated by design at the factory. Based on previous experience with a TPS crack in this location, the condition was approved for flight.

A debris inspection of Pad 39A was performed after launch. One FRSI plug from the Orbiter base heat shield was the only flight hardware found. Launch damage to the holddown posts was minimal. EPON shim material on the south holddown posts was intact, but debonded. No frangible nut/ordnance fragments were found. The GH2 vent line had latched properly. Damage to the facility overall was minimal.

A total of 127 film and video items were analyzed as part of the launch and landing data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. A stud hang-up occurred on HDP #4. The stud remained fully extended as the aft skirt ascended. The stud pulled off a piece of the EPON shim, "twanged" briefly after clearing the stud hole, and dropped into the holddown post. No ordnance debris fell from any of the HDP DCS/stud holes. Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal.

OV-102 carried three ET/ORB umbilical cameras. Imagery from these cameras revealed approximately 60 percent of the LH bipod ramp closeout was missing to a depth that exposed part of the spindle housing along with some of the intertank acreage foam at the leading edge of the ramp (26" x 10" total damage site). Debris damage to Orbiter TPS was greater than average, including a 9"x4.5"x0.5" damage site on the lower surface, and may have been caused by the loss of the ET foam. Loss of the bipod ramp closeout could be the result of TPS material failure on the ET intertank acreage due to inadequate venting. This event appeared similar to the occurrence on STS-7. IFA STS-50-I-01 was taken, and as a result, additional vent holes were drilled around the ET-48 (STS-46), ET-45

(STS-47), and ET-49 (STS-53) bipod ramp closeouts. The vent holes relieve any possible trapped gas pockets in foam-over-foam ET intertank TPS. In addition, the RH jack pad closeout and some adjacent foam was missing (6 inch diameter divot).

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The frustums exhibited a total of 41 debonds over fasteners. The HDP #4 stud hole was broached due to a stud hang-up at lift off as observed in the launch films. A 6"x3" piece of the EPON shim material had been pulled off by the stud. A small piece of the HDP #3 EPON shim was missing prior to water impact (sooted substrate). All Debris Containment System (DCS) plungers were seated properly. This was the eighth flight utilizing the optimized link.

A detailed post landing inspection of OV-102 (Columbia) was conducted on 9 July 1992 (10th landing at KSC). The Orbiter TPS sustained a total of 184 hits, of which 45 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 141 hits, of which 28 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of Orbiter TPS debris hits was greater than average and the number of hits one inch or larger was much higher than average. The most significant tile damage measured 9.0" x 4.5" x 0.5", spanned three tiles, and was located approximately 3 feet outboard of the LH2 ET/ORB umbilical.

An expended detonator/electrical connector from the umbilical separation system fell to the runway when the RH (LO2) ET door was opened. The EO-2 and EO-3 separation ordnance device plungers appeared to have functioned properly. Examination of the windows revealed on-orbit debris impacts to windows #2, 3, 4, 6, and 8. The depth of the impacts ranged from 0.0029 to 0.0055 inches, exceeding the acceptance criteria of 0.0006 inches. The depth of the impact site on window #4 was not measured but was estimated to be greater than 0.004 inches.

A variety of residuals were present in the Orbiter window samples and originated from sources such as Orbiter TPS, Orbiter window polishing compound, SRB BSM exhaust residue, natural landing site products, organics, and paint. Samples from tile damage sites indicated primarily Orbiter thermal protection system (TPS) materials. The damage site on the vertical stabilizer revealed traces of a structural compound of unknown origin. However this material is similar to that used on this and other types of spacecraft hardware as a structural coating material. These data do not indicate a single source of damaging debris as all of the other materials have been previously documented in post-landing samples.

A total of 12 Post Launch Anomalies, including three IFA candidates, were observed during this mission assessment.

2.0 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

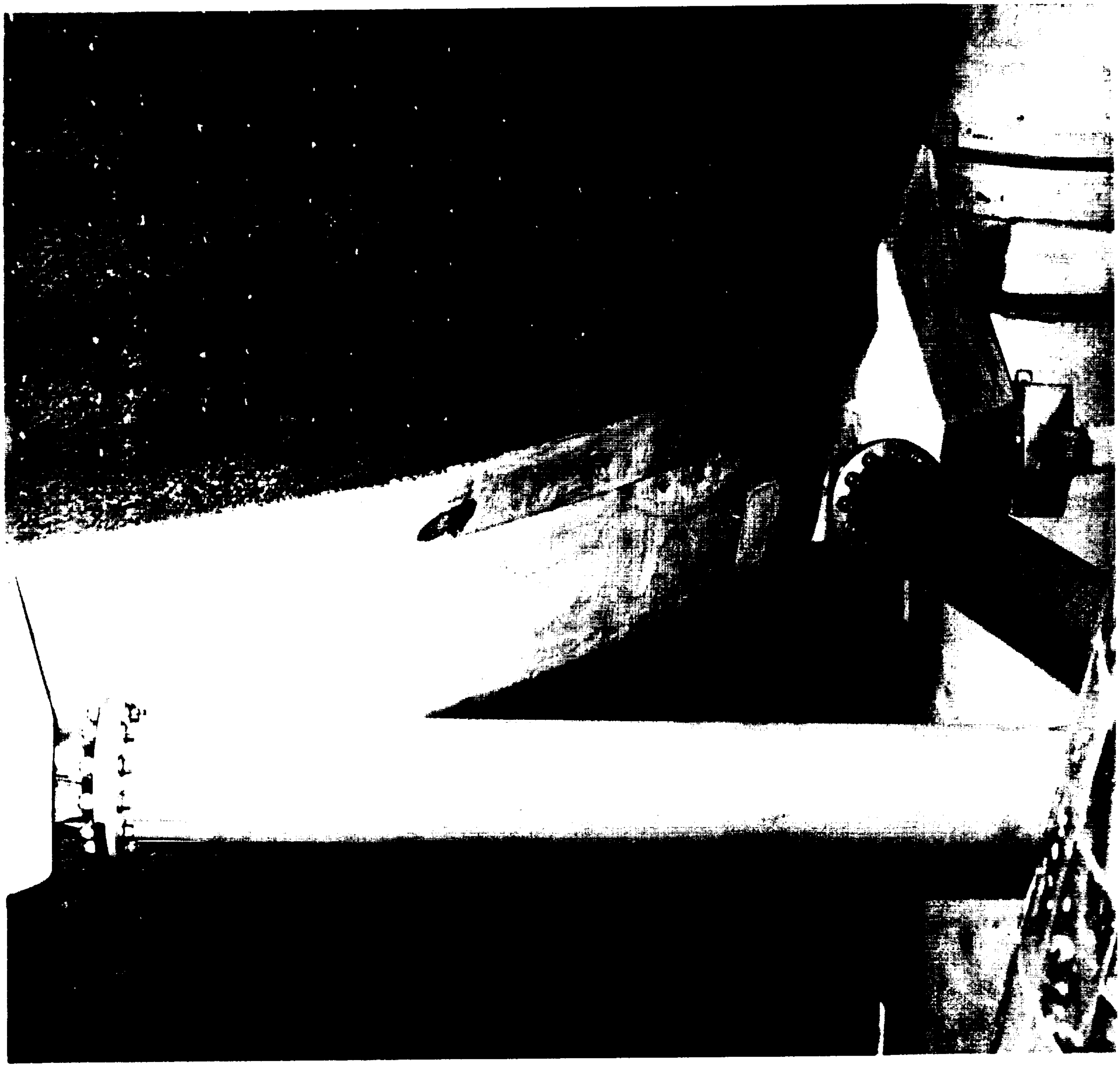
A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 24 June 1992 from 1345 - 1500 hours. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (12th flight), ET-50 (LWT 43), and BI-051 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Team during the T-3 hour hold.

There were no significant vehicle anomalies. Prior to the S0007 countdown, the External Tank had sustained F.O.D. damage in two places. Damaged foam, measuring 8.5" x 5.8" x 3.4" max, on the -Y (LH) thrust strut/longeron (knuckle) closeout was repaired with BX-250 (PR-ET-50-TS-0021). No substrate damage occurred. The object which had been dropped from an upper level and caused the damage had not been found.

High pressure metal tubing, approximately 2.5 feet long by 0.25 inches in diameter, fell from an undetermined location and damaged Super Light Ablator (SLA) on the crossbeam cable tray near the LO2 feedline. The damaged area, measuring 0.9" x 0.7" x 0.5" deep, was repaired with SLA Type 1 (PR-ET-50-TS-0022). The tubing had apparently also damaged two Orbiter tiles. SLA in an adjacent area was damaged by personnel repairing the Orbiter tiles. This area of damage was determined to be acceptable for launch per drawing (PR-ET-50-TS-0023). PER's were written on these two incidents.

A sheared bolt (no bolt head) was present in the kick plate on the east side of the north raised deck area. A bolt was missing from the MLP deck plate electrical box feedthrough east of the RH SRB. These discrepancies were corrected real-time by Pad Operations and no items were entered in S0007, Appendix K.



Bipod jack pad closeouts prior to cryogenic fuel loading

LH2 ET/ORB umbilical, including aft pyrotechnic canister closeout and 17-inch flapper valve actuator access port foam plug closeout, prior to cryogenic fuel loading.

3.0 LAUNCH

STS-50 was launched at 25:16:12:23 GMT (12:12:23 p.m. local) on 25 June 1992.

3.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 25 June 1992 from 0645 to 0840 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no conditions outside of the established data base. Ambient weather conditions at the time of the inspection were:

Temperature:	76.9 F
Relative Humidity:	87.2 %
Wind Speed:	6.7 Knots
Wind Direction:	161 Degrees

The portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

3.2 ORBITER

No Orbiter tile or RCC panel anomalies were observed with the exception of a 3-inch piece of cloth tape on a lower surface tile near the LH wing tip. The F1U, F3U, and all LH FRCS thruster paper covers were wet from recent rain, but intact. The water spray boiler plugs were intact. Light frost was present at the SSME #1 and #2 heat shield-to-nozzle interfaces. Condensate was present on all SSME heat shields and on base heat shield tiles. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

3.3 SOLID ROCKET BOOSTERS

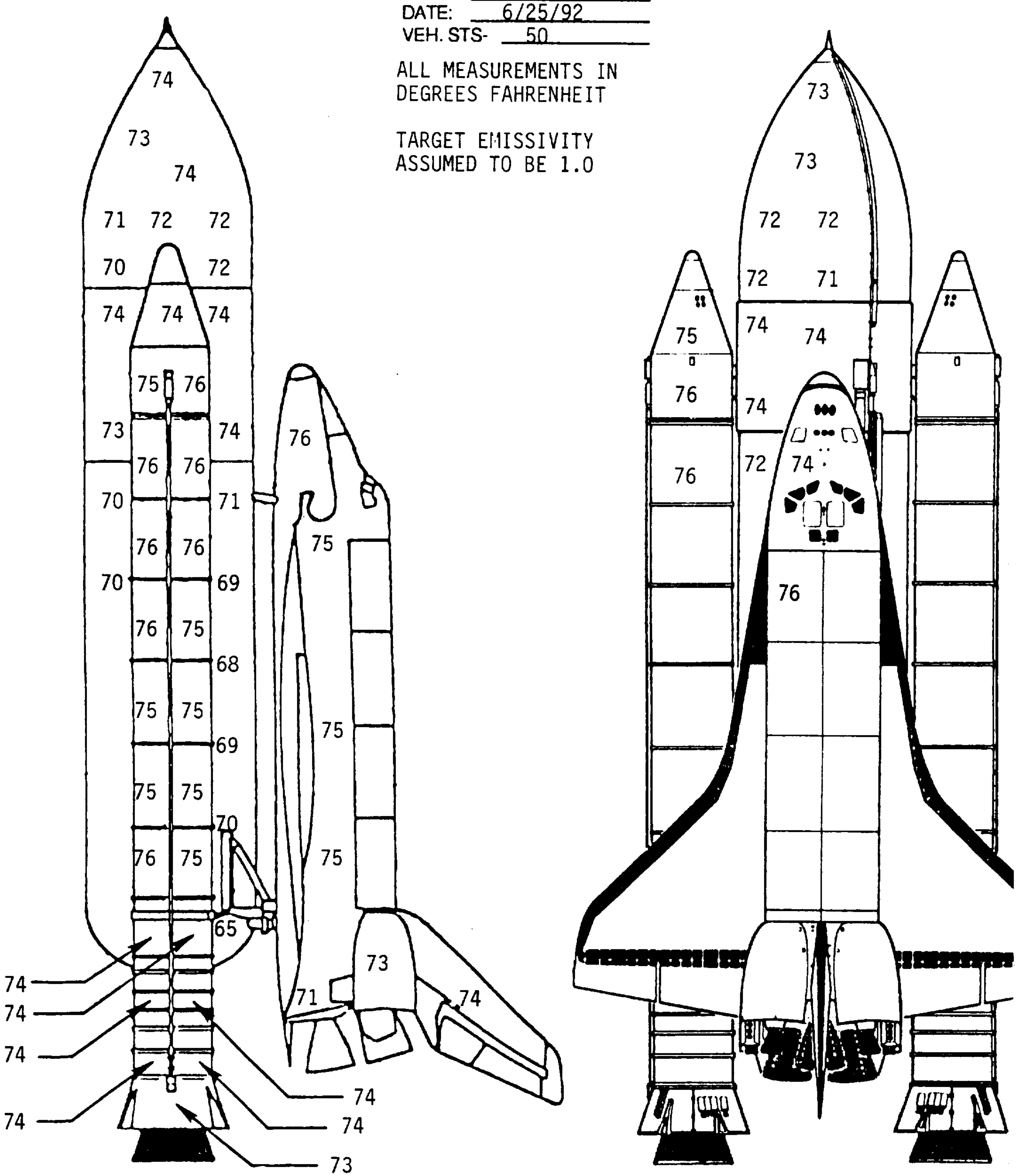
No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 73 and 78 degrees F. In comparison, temperatures measured by the hand-held Cyclops radiometer ranged from 74 to 80 degrees F and the GEI (Ground Environment Instrumentation) measured temperatures that ranged from 77 to 82 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 78 degrees F, which was within the required range of 44-86 degrees F.

SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0645 - 0845 EDT
DATE: 6/25/92
VEH. STS- 50

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0

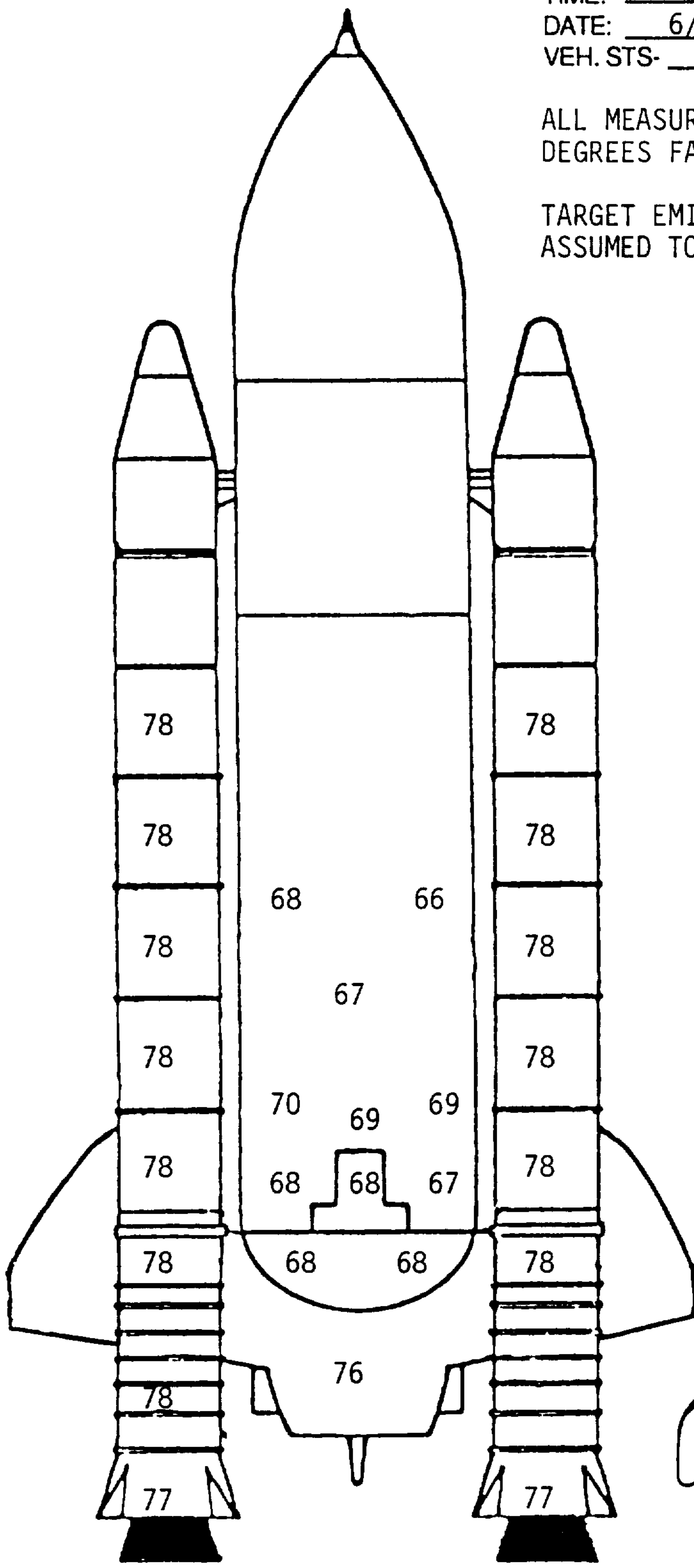


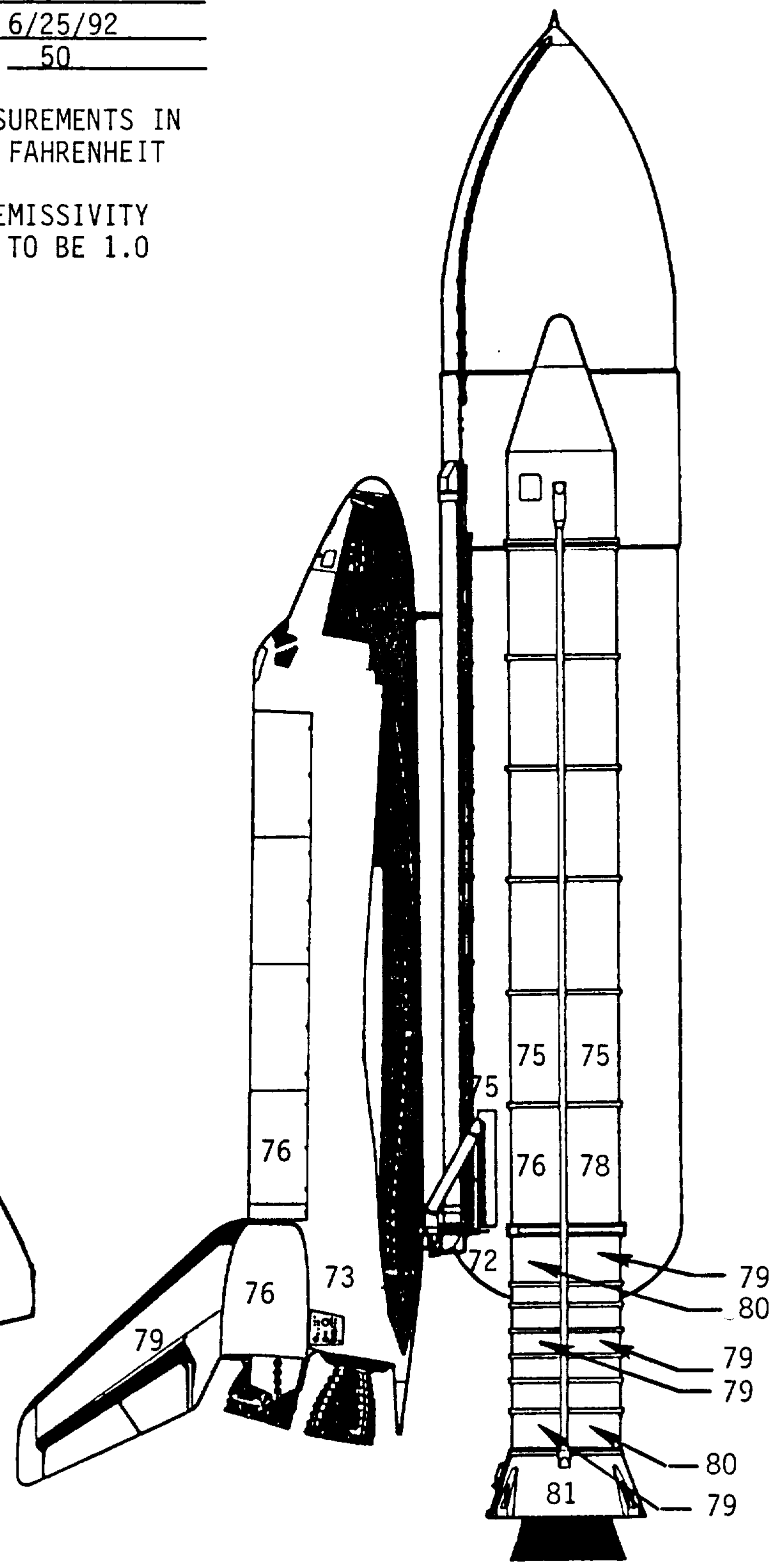
SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0645 - 0845 EDT
DATE: 6/25/92
VEH. STS- 50

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0





EGG/V-343C

3.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0415 to 1200 hours and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

There was very light condensate, but no ice/frost accumulation, on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. The pressurization line and support ramps were in nominal configuration. The portable STI measured surface temperatures that averaged 73 degrees F on the ogive and 72 degrees Fahrenheit on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 74 degrees F on the ogive and 71 degrees F on the barrel, while SURFICE predicted temperatures of 70 degrees F on the ogive and 66 degrees F on the barrel.

The intertank TPS acreage was dry. Frost spots were present in the stringer valleys at both the LH2 and LO2 tank-to-intertank flanges. No unusual vapors or ice formations were present on the ET umbilical carrier plate. Both the portable STI and the Cyclops radiometer measured temperatures that averaged 74 degrees F.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 69 degrees F on the upper LH2 tank and 68 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 69 degrees F on the upper LH2 tank and 70 degrees F on the lower LH2 tank; SURFICE predicted temperatures of 57 degrees F on the upper LH2 tank and 65 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, bipod jack pad closeouts, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joints. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry. A 10" x 0.25" crack occurred in the forward surface of the -Y ET/SRB cable tray near the longeron closeout interface. There was no offset and no ice/frost in the crack. The condition was accepted for launch.

Typical amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

STS-50	TEST S0007 LAUNCH	DATE: 25 June 1992	T-0 TIME: 12:12:23 DATE: 6/25/92	NASA KSC Ice/Frost/Debris Team

ORBITER 102 | ET 50 | SRB BI-051 | MLP 3 | PAD A

LO2 — CHILLDOWN TIME: 03:41 FAST FILL TIME: 04:21 SLOW FILL TIME: 04:07 REPLENISH TIME: 06:26

LH2 — CHILLDOWN TIME: 03:35 FAST FILL TIME: 04:21 SLOW FILL TIME: 03:42 REPLENISH TIME: 06:04

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
415	75.80	85.8	71.44	11	186	II	6.49	68.06	0.0027	-0.2698	II	6.49	64.85	0.0048	-0.2372	II	4.62	61.65	0.0050	-0.1650	II	4.18	60.78	0.0050	-0.1491
430	75.00	86.4	70.85	11	191	II	6.49	67.34	0.0027	-0.2627	II	6.49	64.10	0.0048	-0.2302	II	4.62	60.85	0.0050	-0.1595	II	4.18	59.98	0.0049	-0.1441
445	73.80	90.0	70.81	7	200	II	4.13	64.92	0.0030	-0.1754	II	4.13	60.23	0.0048	-0.1446	II	2.94	55.88	0.0047	-0.0967	II	2.66	54.77	0.0046	-0.0866
500	73.60	91.6	71.11	3	186	II	1.77	60.01	0.0026	-0.0996	II	1.77	51.71	0.0038	-0.0748	II	1.26	49.74	0.0040	-0.0690	II	1.14	49.74	0.0040	-0.0690
515	74.00	92.0	71.63	3	159	II	1.77	60.58	0.0026	-0.1023	II	1.77	52.32	0.0038	-0.0774	II	1.26	50.32	0.0040	-0.0716	II	1.14	50.32	0.0040	-0.0716
530	74.60	92.0	72.23	3	170	II	1.77	61.30	0.0026	-0.1058	II	1.77	53.09	0.0039	-0.0809	II	1.26	51.08	0.0041	-0.0751	II	1.14	51.08	0.0041	-0.0751
545	74.80	91.8	72.37	3	162	II	1.77	61.50	0.0026	-0.1068	II	1.77	53.31	0.0039	-0.0819	II	1.26	51.29	0.0041	-0.0761	II	1.14	51.29	0.0041	-0.0761
600	75.20	91.2	72.58	2	133	II	1.18	60.02	0.0024	-0.1086	II	1.18	53.12	0.0038	-0.0837	II	0.64	51.69	0.0041	-0.0779	II	2.78	57.30	0.0048	-0.1004
615	74.60	90.2	71.67	3	123	II	1.77	60.92	0.0025	-0.1041	II	1.77	52.70	0.0038	-0.0793	II	0.96	50.74	0.0040	-0.0735	II	4.17	60.39	0.0052	-0.1465
630	75.40	88.4	71.89	5	145	II	2.95	64.62	0.0028	-0.1408	II	2.95	58.73	0.0044	-0.1106	II	1.60	51.41	0.0040	-0.0765	II	6.95	64.85	0.0055	-0.2494
645	75.60	88.0	71.96	7	172	II	4.13	66.48	0.0029	-0.1863	II	4.13	61.89	0.0048	-0.1551	II	2.94	57.65	0.0047	-0.1052	II	2.66	56.56	0.0046	-0.0946
700	75.80	87.6	72.03	6	154	II	3.54	65.86	0.0028	-0.1649	II	3.54	60.71	0.0046	-0.1342	II	1.92	52.97	0.0041	-0.0781	II	8.34	66.22	0.0055	-0.3012
715	75.60	88.4	72.09	5	156	II	2.95	64.85	0.0028	-0.1421	II	2.95	58.97	0.0044	-0.1118	II	1.60	51.66	0.0040	-0.0776	II	6.95	65.08	0.0055	-0.2517
730	76.00	88.0	72.36	5	156	II	2.95	65.22	0.0028	-0.1441	II	2.95	59.36	0.0044	-0.1138	II	1.60	52.09	0.0040	-0.0796	II	6.95	65.43	0.0055	-0.2552
745	76.00	88.0	72.36	6	161	II	3.54	66.18	0.0029	-0.1669	II	3.54	61.05	0.0046	-0.1361	II	2.52	56.46	0.0046	-0.0915	II	2.28	55.35	0.0044	-0.0822
800	76.80	86.8	72.76	7	160	II	4.13	67.54	0.0028	-0.1938	II	4.13	63.01	0.0048	-0.1624	II	2.94	58.84	0.0047	-0.1110	II	2.66	57.78	0.0046	-0.1001
815	77.60	87.0	73.62	7	170	II	4.13	68.47	0.0029	-0.2006	II	4.13	64.00	0.0048	-0.1690	II	2.94	59.88	0.0048	-0.1162	II	2.66	58.82	0.0047	-0.1050
830	78.00	86.4	73.82	9	158	II	5.31	69.82	0.0029	-0.2497	II	5.31	66.17	0.0050	-0.2171	II	3.78	62.65	0.0051	-0.1515	II	3.42	61.72	0.0050	-0.1372
845	78.80	84.2	73.83	8	161	II	4.72	69.68	0.0027	-0.2291	II	4.72	65.70	0.0048	-0.1969	II	3.36	61.96	0.0049	-0.1371	II	3.04	60.99	0.0048	-0.1242
900	79.20	82.8	73.80	8	167	II	4.72	69.78	0.0026	-0.2298	II	4.72	65.81	0.0047	-0.1976	II	3.36	62.09	0.0048	-0.1378	II	3.04	61.13	0.0047	-0.1249
915	79.80	81.2	73.84	11	179	II	6.49	71.18	0.0023	-0.3023	II	6.49	68.13	0.0046	-0.2688	II	4.62	65.13	0.0049	-0.1899	II	4.18	64.33	0.0049	-0.1724
930	81.00	77.2	73.59	10	178	II	5.90	71.10	0.0020	-0.2812	II	5.90	67.82	0.0042	-0.2481	II	4.20	64.68	0.0046	-0.1753	II	3.80	63.85	0.0045	-0.1593
945	82.00	75.4	73.90	10	172	II	5.90	71.68	0.0018	-0.2869	II	5.90	68.43	0.0040	-0.2536	II	4.20	65.34	0.0045	-0.1797	II	3.80	64.53	0.0044	-0.1635
1000	82.00	74.6	73.60	12	175	II	7.08	72.02	0.0015	-0.3316	II	7.08	69.23	0.0038	-0.2977	II	5.04	66.51	0.0044	-0.2117	II	4.56	65.76	0.0044	-0.1926
1015	82.20	73.6	73.41	12	172	II	7.08	71.96	0.0014	-0.3308	II	7.08	69.16	0.0037	-0.2969	II	5.04	66.45	0.0043	-0.2112	II	4.56	65.71	0.0043	-0.1922
1030	82.40	72.0	72.98	14	176	II	8.26	72.15	0.0009	-0.3739	II	8.26	69.69	0.0033	-0.3393	II	5.88	67.26	0.0041	-0.2421	II	5.32	66.60	0.0041	-0.2203
1045	82.40	72.4	73.14	14	171	II	8.26	72.26	0.0009	-0.3754	II	8.26	69.80	0.0034	-0.3408	II	5.88	67.38	0.0041	-0.2432	II	5.32	66.71	0.0042	-0.2212
1100	83.20	70.8	73.29	13	167	II	7.67	72.43	0.0009	-0.3569	II	7.67	69.83	0.0033	-0.3225	II	5.46	67.30	0.0040	-0.2303	II	4.94	66.61	0.0040	-0.2096
1115	83.00	71.0	73.17	12	178	II	7.08	72.07	0.0010	-0.3318	II	7.08	69.28	0.0034	-0.2979	II	5.04	66.59	0.0041	-0.2123	II	4.56	65.87	0.0041	-0.1932
1130	83.00	70.0	72.77	14	172	II	8.26	72.20	0.0006	-0.3743	II	8.26	69.74	0.0030	-0.3398	II	5.88	67.34	0.0039	-0.2427	II	5.32	66.67	0.0039	-0.2209
1145	83.20	70.4	73.13	12	162	II	7.08	72.10	0.0010	-0.3322	II	7.08	69.31	0.0033	-0.2983	II	5.04	66.64	0.0040	-0.2127	II	4.56	65.92	0.0040	-0.1936
1200	82.20	72.0	72.79	12	158	II	7.08	71.53	0.0012	-0.3256	II	7.08	68.71	0.0035	-0.2918	II	5.04	65.99	0.0041	-0.2075	II	4.56	65.26	0.0041	-0.1888
T-0	82.60	72.4	73.34	13	154	II	7.67	72.27	0.0011	-0.3549	II	7.67	69.65	0.0035	-0.3206	II	4.16	65.11	0.0042	-0.1769	II	18.07	72.53	0.0017	-0.7082
Avg	76.04	79.99	70.54	8.18	SSE		4.82	65.83				4.82	61.46				3.32	58.02				4.27	59.70		

Period of Ice Team Inspection

Figure 3. "SURFICE" Computer Predictions

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Amounts of ice/frost on the top, outboard, and inboard sides of the LH2 ET/ORB umbilical purge barrier were less than usual. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost had also formed on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. Normal venting of helium purge gas had occurred during tanking, stable replenish, and launch. There were no unusual vapors emanating from the umbilicals nor any evidence of cryogenic drips. No ice or frost had formed on the cable tray vent hole or on the 17-inch flapper valve actuator access port foam plug.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle, but released prematurely at the upper strut fairing attach point due to entanglement of the pull cord. There was no flight hardware contact or TPS damage.

The summary of Ice/Frost Team observations/anomalies consisted of five OTV recorded items:

Anomaly 001 and PR-ET-50-TS-0025 documented a 10" x 0.25" crack on the forward side of the -Y ET/SRB vertical strut/cable tray. The crack occurred in an area where the stress relief cut had been eliminated by design at the factory. Based on previous experience with a TPS crack in this location, the condition was approved for flight.

Anomaly 002 recorded ice/frost spots in the intertank stringer valleys at both the LH2 and LO2 tank-to-intertank flanges in the -Y-Z quadrant. The ice/frost was acceptable per NSTS-08303.

Anomaly 003 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets. These ice and frost formations were acceptable per NSTS-08303.

Anomaly 004 (documentation only) recorded ice/frost formations on the LO2 umbilical purge vents and LH2 umbilical purge vents, purge barrier (baggie), and LH2 recirculation line bellows. The ice/frost formations were acceptable per NSTS-08303.

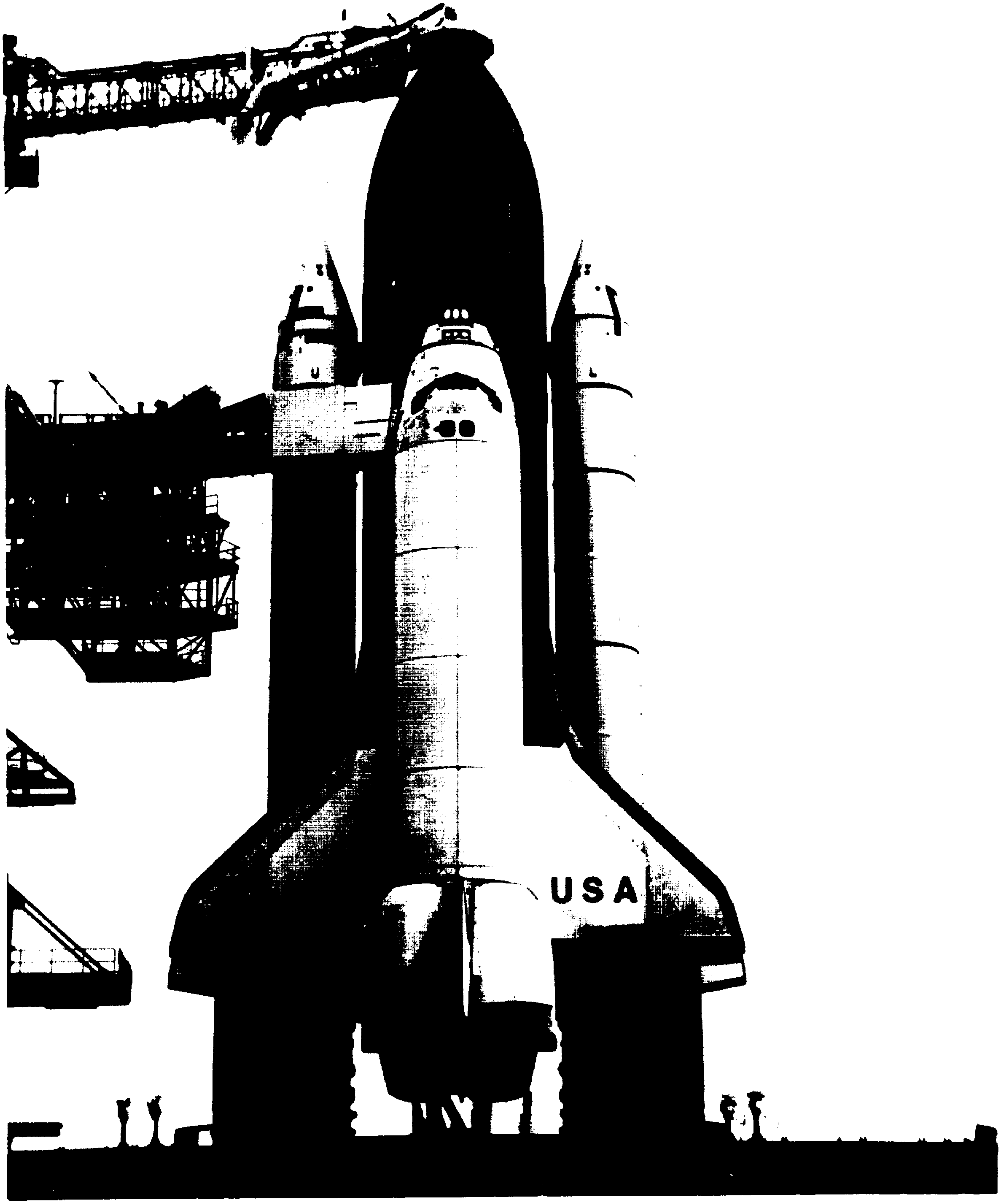
Anomaly 005 (documentation only) recorded 4 areas of froth on the LH2 aft dome -Z manhole cover. The presence of froth was acceptable per NSTS-08303.

3.5 FACILITY

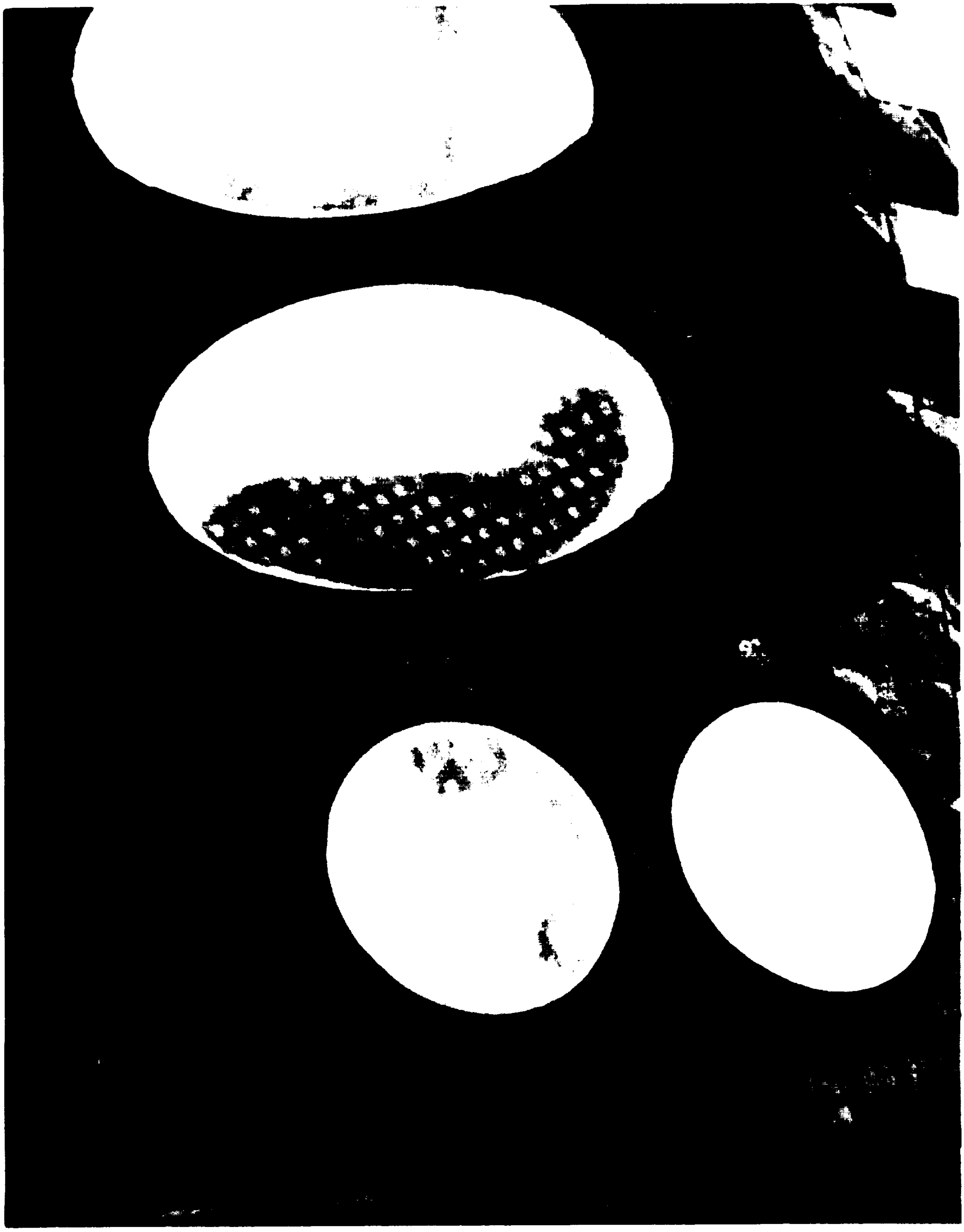
All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas with the exception of a loose electrical conduit cap on the east side of the SSME flame exhaust hole.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The GH2 vent line modification prevented ice from forming, but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. No icicles had formed on the GOX vent ducts.

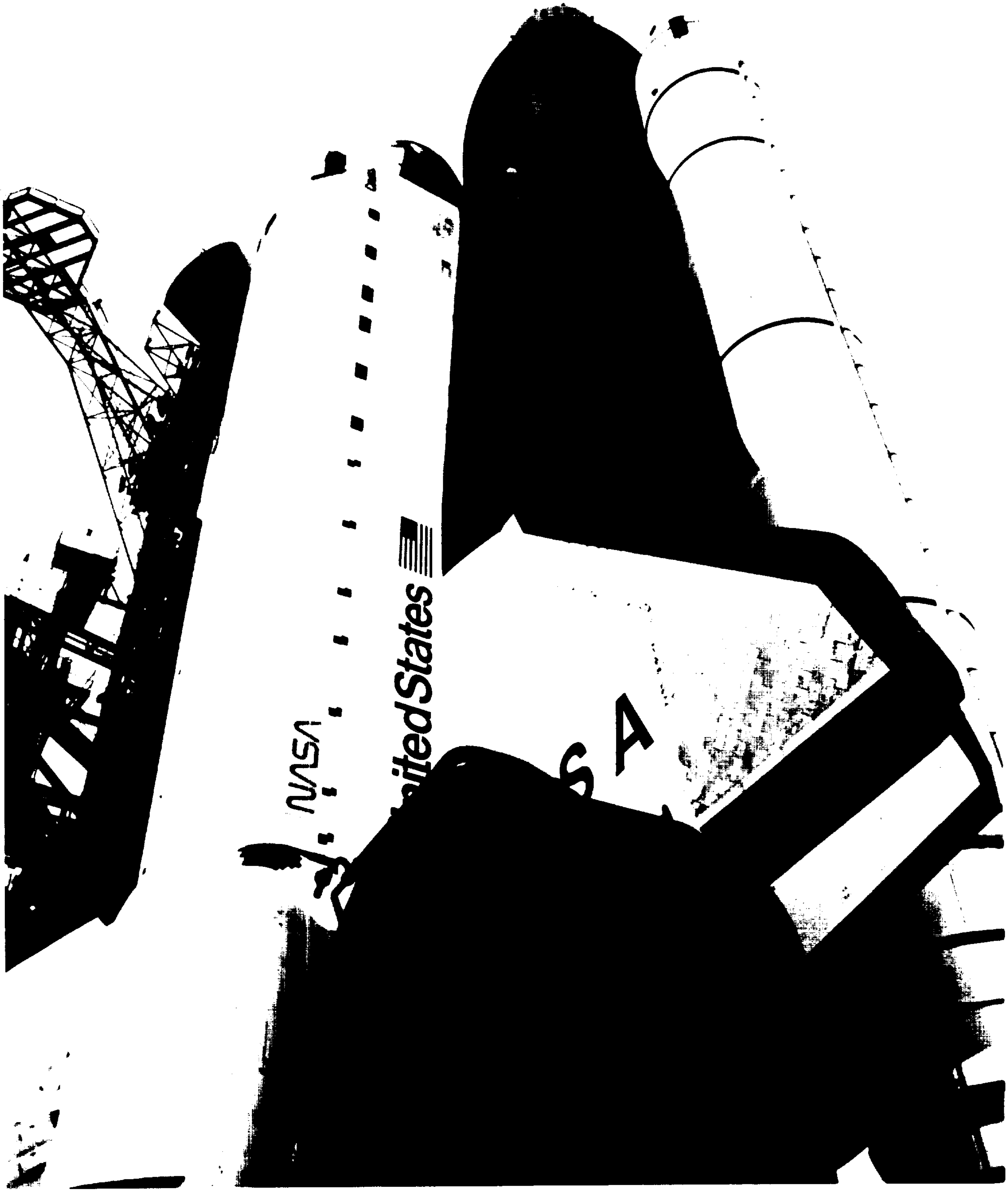


OV-102 Columbia, ET-50 (LWT 43), and BI051 SRB's

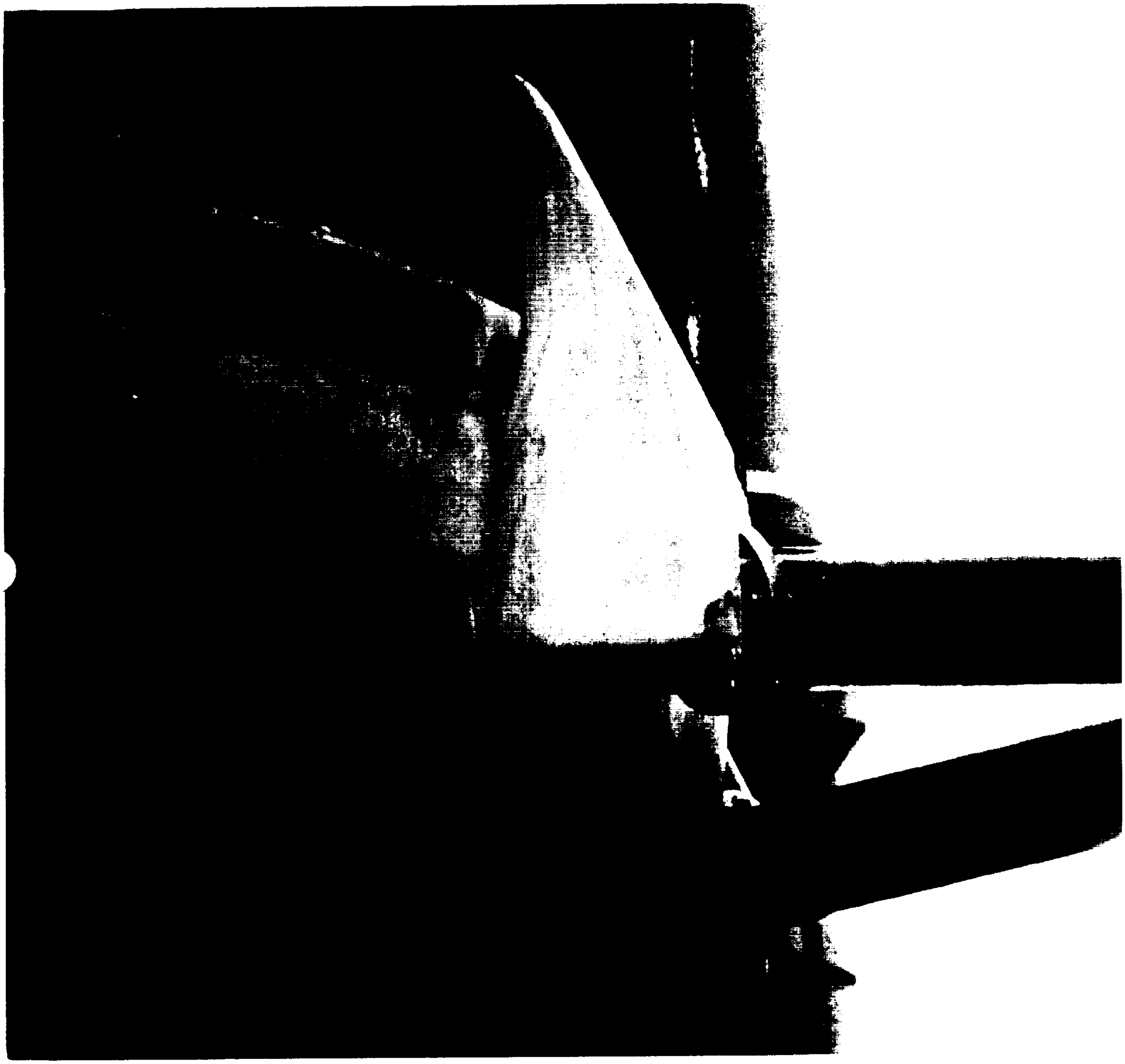


The LH forward RCS thruster paper covers were wet, but intact

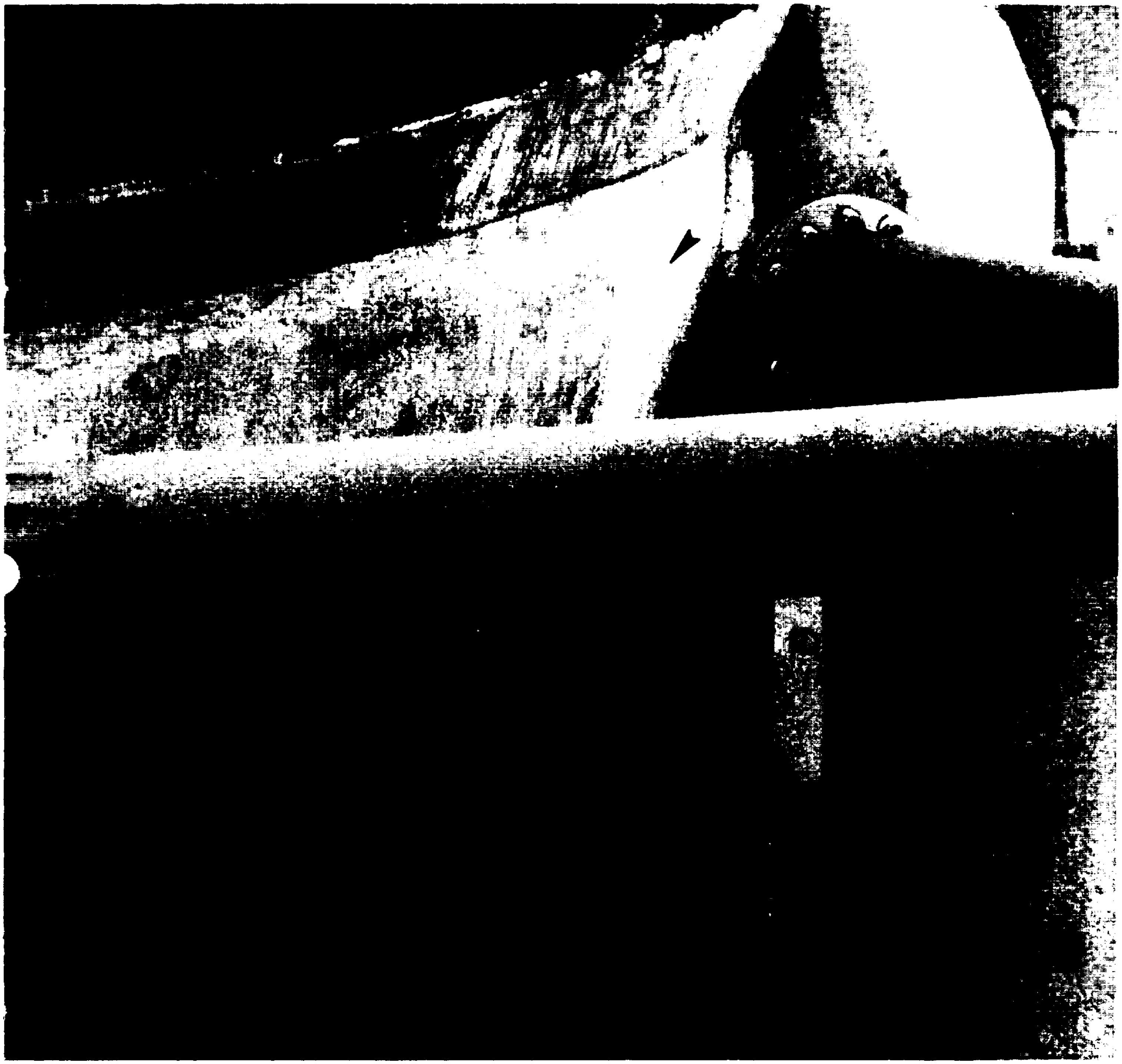
Overall view of Shuttle Main Engines. Light frost was present on the SSME #1 and #2 heat shield-to-nozzle interfaces. All three SSME engine mounted heatshields and some base heat shield tiles were wet with condensate.



Very light condensate, but no ice or frost accumulations, were present on the ET LO2 and LH2 tank TPS acreage.

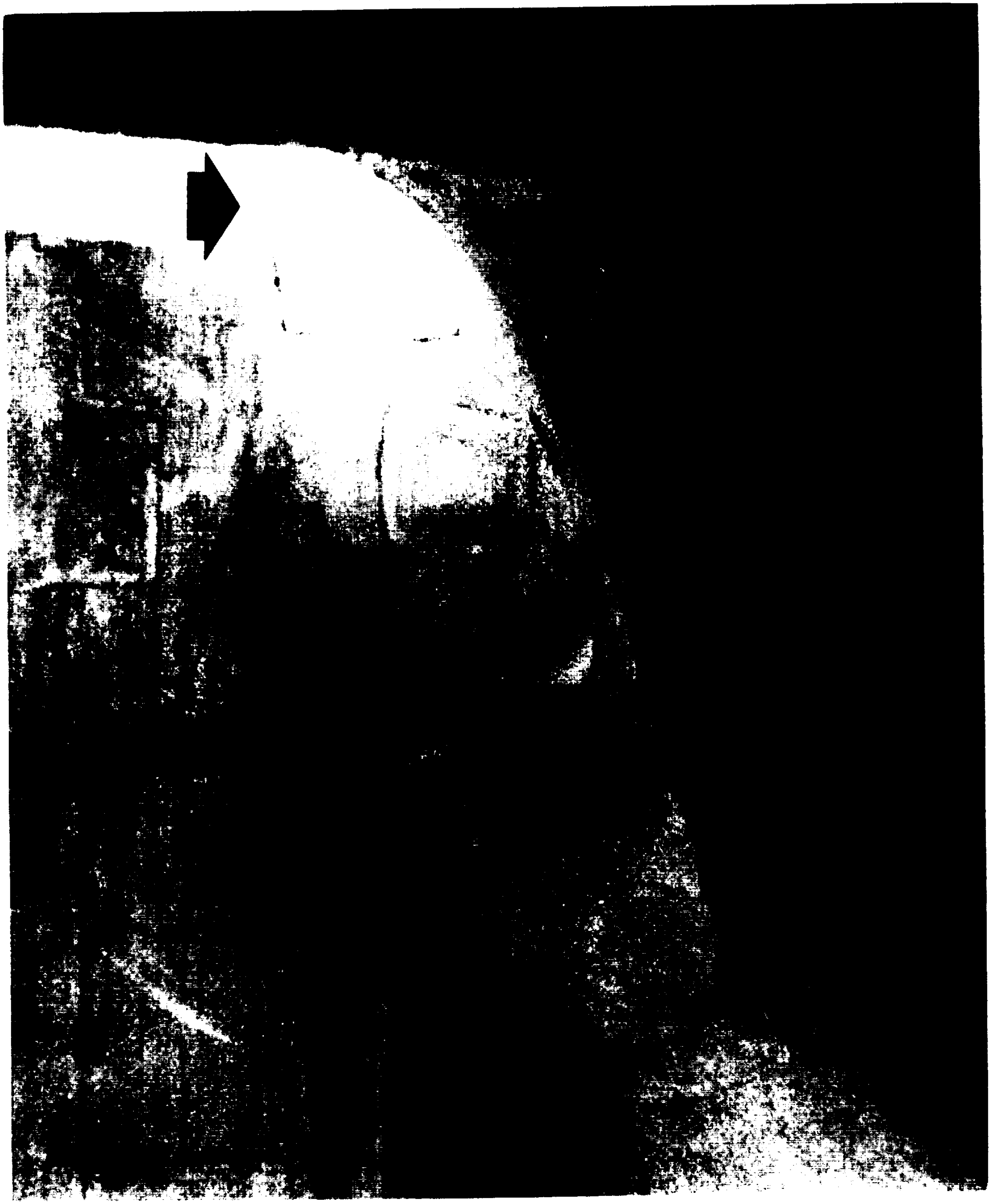


LH (-Y) bipod ramp closeout after cryogenic fuel loading. There were no visual indications to account for the loss of 60 percent of the ramp closeout and a portion of the intertank acreage TPS sometime during flight.



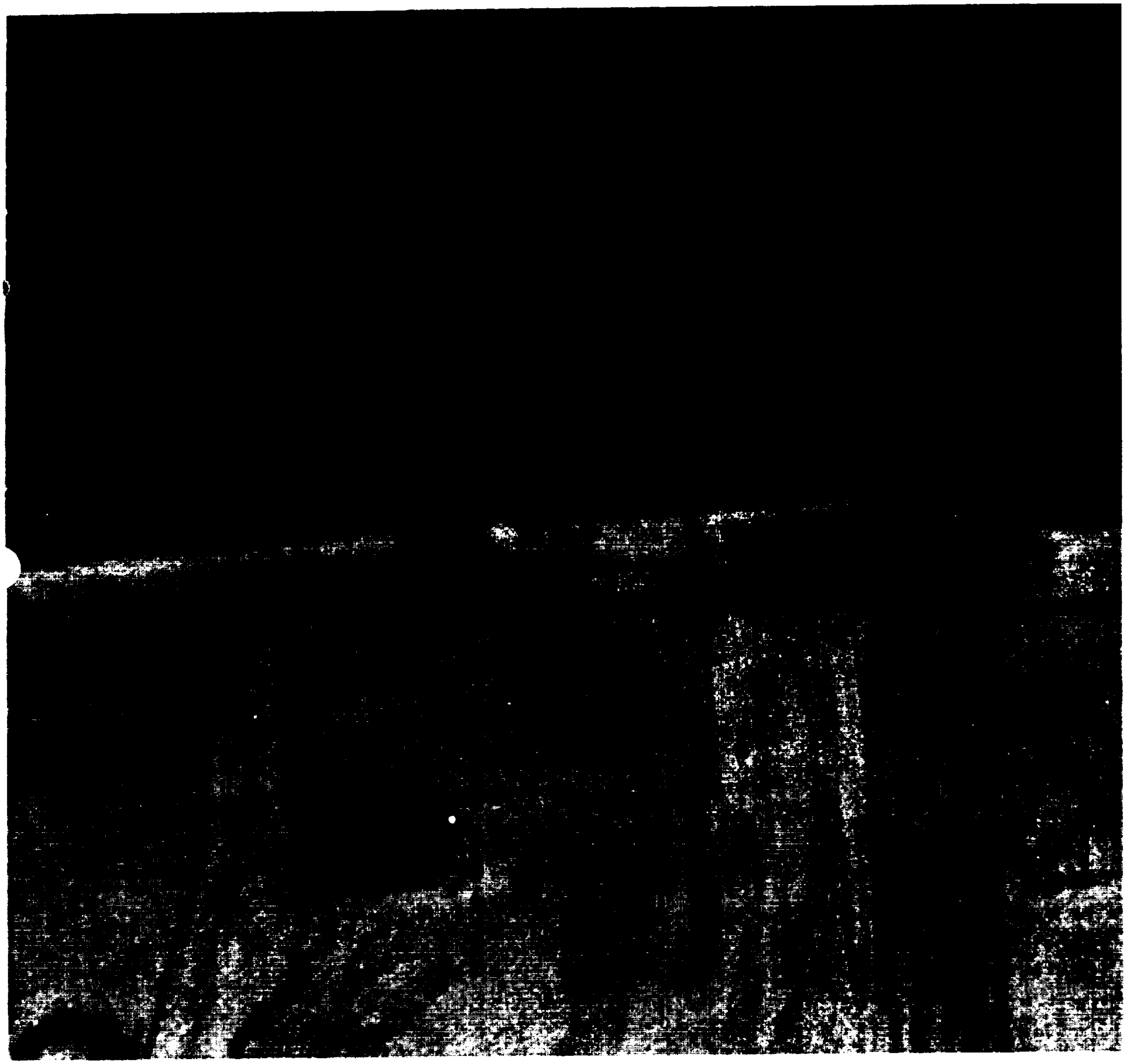
RH (+Y) bipod jack pad closeout after cryogenic fuel loading. There was no ice/frost accumulation on the closeout or bond line and no sign of debond. However, ET separation photography revealed the loss of the closeout sometime during flight.

Typical amounts of crusty ice/frost had formed in the LO2 feedline lower bellows

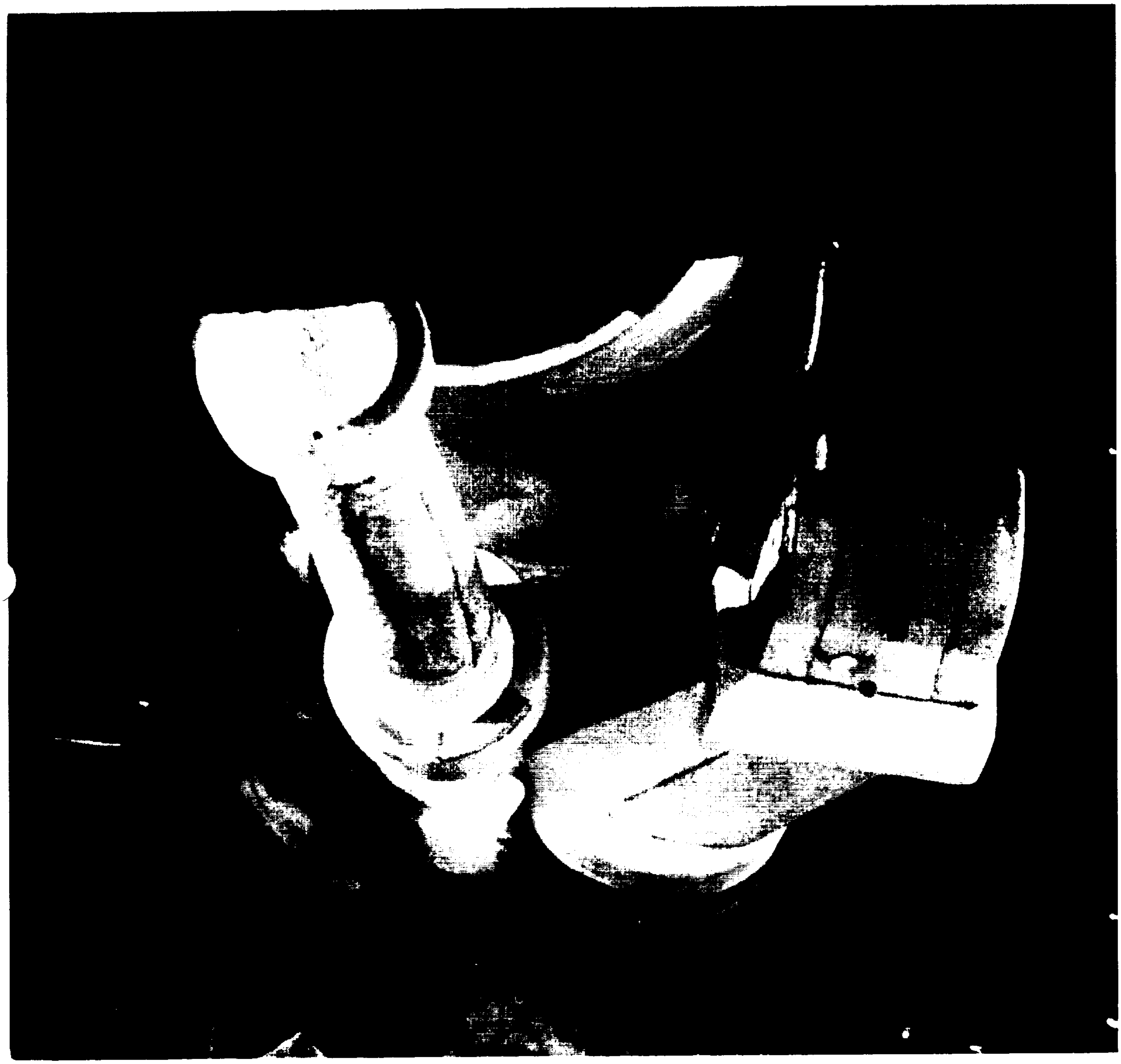


BX-250 repair to an F.O.D. damage site on the LH (-Y) thrust strut to longeron (knuckle) closeout exhibited no ice or frost accumulations after cryogenic fuel loading.

A crack 10 inches long appeared in the -Y vertical strut cable tray forward facing surface near the tank acreage interface. A stress relief cut in the TPS to allow for structural movement had been deleted by design.



The 1/4-inch wide crack exhibited no offset and there was no ice or frost in the crack. The condition was accepted for launch.



Ice/frost formations on the inboard side of the umbilical/ purge barrier, the lower plate gap purge vent, and in the LH2 recirculation line bellows were typical. Ice/frost accumulated on the thin foam and bondline around the aft pyro canister

A loose electrical conduit cap on the east side of the SSME flame exhaust hole was removed

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS and Pad acreage was conducted on 25 June 1992 from Launch + 2 to 4 1/2 hours. No flight hardware or TPS materials associated with this mission were found with the exception of one FRSI plug (possibly from the Orbiter base heat shield).

Five pieces of HDP shim material were found approximately 100 feet east of the pad surface in the acreage area. One side of one piece was coated with primer. None appeared to be from this launch.

South SRB holddown post erosion was typical. EPON shim material was intact on all south holddown posts. However, the sidewall material was partially debonded and showed a considerable number of voids. There was no visual indication of a stud hang-up on any of the south holddown posts. No ordnance fragments were found in the south HDP stud holes. All of the north HDP doghouse blast covers were in the closed position and exhibited greater than normal erosion. HDP #4 blast cover had an approximately 12 inch long crack along the southeast ridge. Pieces of material were missing from corners of HDP #3, #7, and #8 blast covers. The SRB aft skirt purge lines were in place but slightly damaged. The SRB T-0 umbilicals exhibited minor damage including deformation of the sacrificial connector savers.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of damage. The GH2 vent line latched on the eighth tooth. There were no loose cables, but the north latch appeared to have contacted the north saddle stabilizer. The damage from this contact was minimal and has occurred on previous launches.

Damage to the facility included:

1. A lighting fixture found on the west edge of the FSS 95' level. The fixture appeared to have originated from the east side of the elevator enclosure.

2. Two damaged electrical junction box doors on the 95 and 175 foot levels of the FSS.

3. Two detached FSS 175 and 235 level signs were found on the FSS.

4. Loose piece of sheet metal (2' x 3') on the roof of the RSS.

5. Five pieces of facility foam were found on the RSS 215 foot level.

6. Miscellaneous, typical facility hardware were found.

The ablative material at the bottom of the SRB flame deflector was damaged more than usual. Many broken pieces of this material were blown to the north by the SRB exhaust plume causing damage to the perimeter fence, two lighting fixtures, and one wood utility pole.

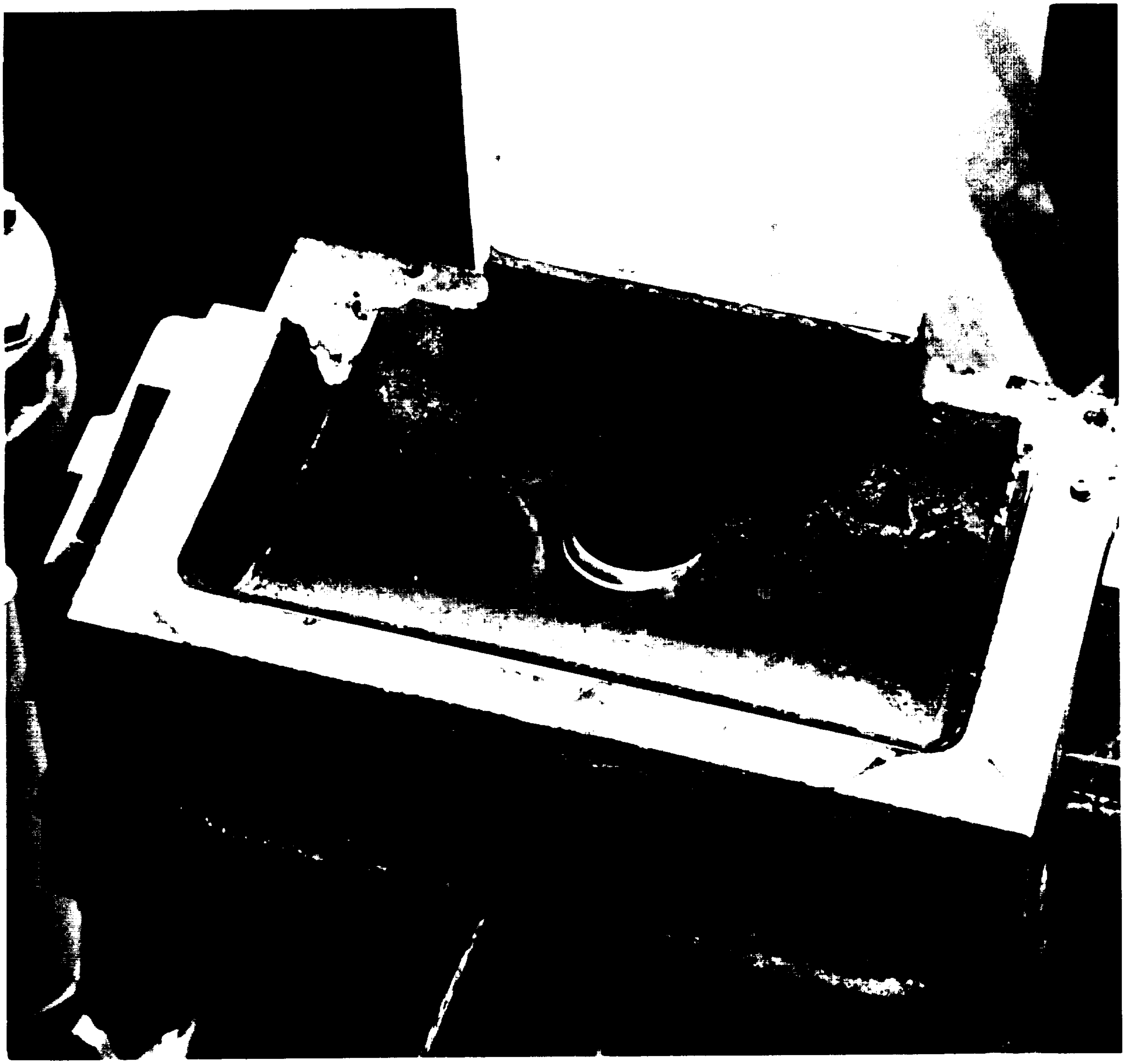
All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

An inspection of the beach from UCS-9 to the Titan complex, the beach road, the railroad tracks, and the water areas around the pad and under the flight path was canceled due to inclement weather from the tropical depression.

MLP-3 was configured with overpressure sensors at the top of both TSM's, at the bottom of both SRB exhaust holes, and at the bottom of the SSME exhaust hole. All sensor readings were consistent with previous launches and within nominal limits.

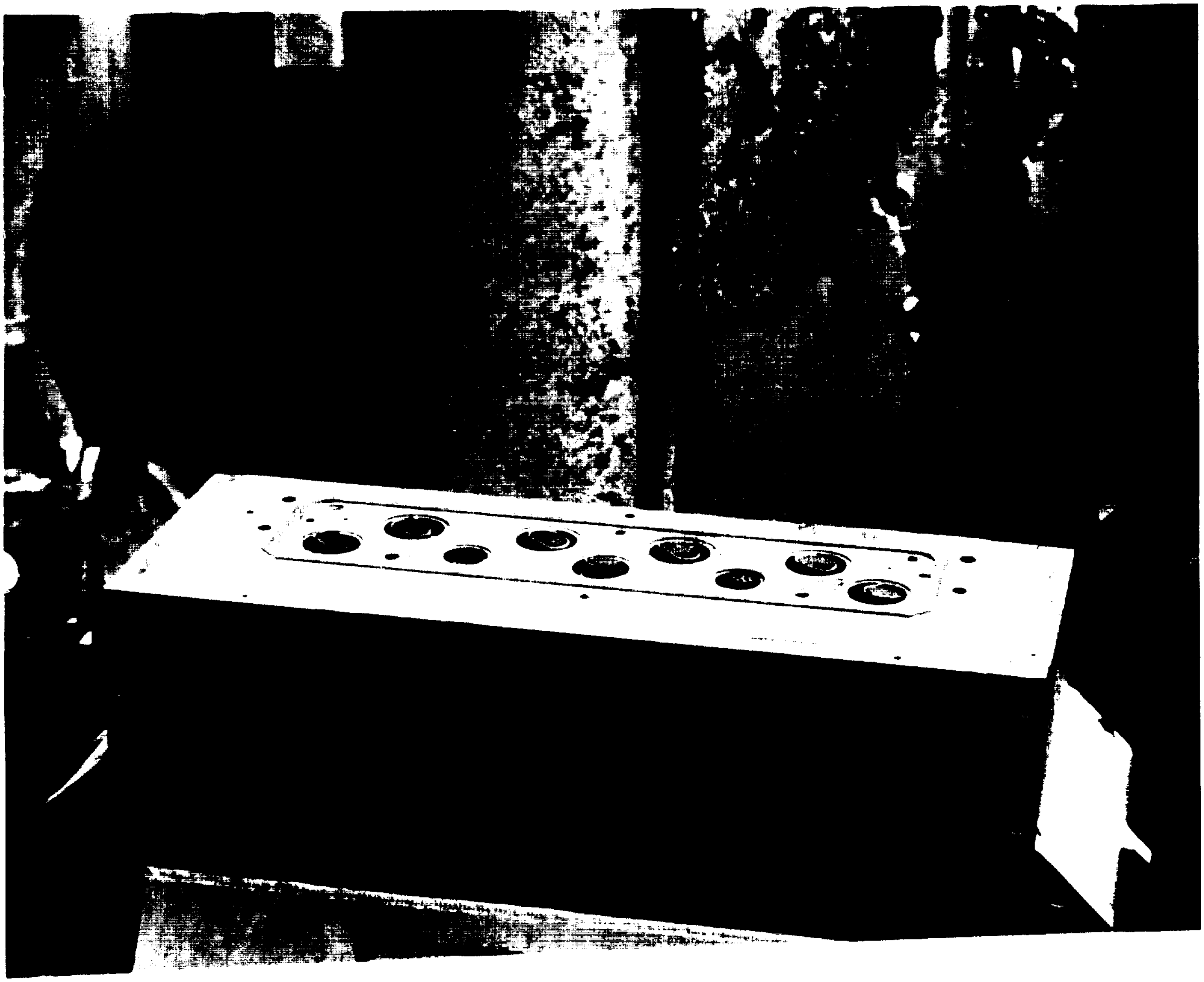
Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights. A total of 49 particles were imaged in the T+145.5 to 360.0 second time period. Twenty-five of the particles were imaged by only one radar, 21 particles were imaged by two radars, and 3 particles were imaged by all three radars. Compared to STS-49, both the number of detected particles and the total number of radar detections were noticeably lower.

Post launch pad inspection anomalies are listed in Section 9.



Plume erosion of the south SRB holddown posts was typical. EPON shim material was intact, but debonded along the sidewalls.

ORIGINAL PAGE
COLOR PHOTOGRAPH



The SRB T-0 umbilicals sustained minor damage

5.0 FILM REVIEW AND PROBLEM REPORTS

Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 106 film and video data items, which included thirty-seven videos, forty-six 16mm films, nineteen 35mm films, and four 70mm films, were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

SSME ignition, Mach diamond formation, and gimbal profile appeared normal. Free burning hydrogen drifted upward to the OMS pods and north under the body flap (RSS STI, C/S-2 STI, OTV 051, 063, 070). No discolorations or unusual streaks were visible in the Mach diamonds or exhaust plumes (E-2, 3, 19, 20).

Fore-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster occurred during the early stages of SSME ignition (E-19, 20, 76). The motion was similar to that observed on previous launches.

SSME ignition caused numerous pieces of ice/frost to fall from the ET/Orbiter umbilicals. No damage to Orbiter tiles or ET TPS was visible. There were no unusual vapors or cryogenic drips from the ET/ORB umbilicals during tanking, stable replenish, ignition, or liftoff (OTV 009, 054, 056, 063, 064, E-4).

SSME ignition vibration and acoustics caused the loss of tile surface coating material from eight places on the base heat shield (E-6, 18, 19, 23, 24) and one place on the LH OMS pod base heat shield (E-19).

An orange GSE tile shim originated near the R1A thruster and fell aft during SSME ignition (E-19, frame 2950).

Light frost was present in the ET GOX vent louvers. There was no TPS damage to the ET nosecone, footprint, or fairing (OTV 060, 061). ET "twang" of approximately 32 inches was typical (E-79). The ET nosecone/pressure spike returned to the 13 inch mark at T-0.

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 063). A small rectangular object, possibly a metal parts tag, fell from the LO2 T-0 umbilical during SSME ignition. The object did not contact flight hardware (E-17). Separation of the GUCP from the External Tank was nominal (OTV 004). The GH2 vent line retracted normally and latched with no rebound. There was no excessive slack in the static retract lanyard (E-33, 41, 42, 48, 50).

A stud hang-up occurred on HDP #4 (E-7, 10). The stud remained fully extended as the aft skirt ascended. The stud pulled off a 6"x3" piece of the EPON shim, "twanged" briefly after clearing the stud hole, and dropped into the holddown post. No ordnance debris fell from any of the HDP DCS/stud holes.

A 2"x1" object, most likely a piece of the EPON shim, fell from the HDP #3 aft skirt foot as the vehicle lifted off (E-10). Loss of the shim material is consistent with findings from the SRB Post Flight Inspection.

HDP #1 and #5 shoe rotation appeared typical. A 3-inch long piece of dark debris, possibly a K5NA trimming or piece of tape, first appeared from the area behind the DCS housing at T-0 and fell into the exhaust hole (EX1, EX4). Although the -Z sides released first, separation of the SRB T-0 umbilicals from the aft skirts was nominal (EX2, EX3).

A semi-rigid object, possibly a piece of SRB thermal curtain tape or HDP firing line tape, first appeared in the RH SRB exhaust hole near HDP #4, passed between camera E-15 and the center rainbird, and moved north away from the vehicle (E-1, 4, 15). A bright object was visible near the RH SRB plume in film item E-222 at 16:12:25.381 GMT and may be the large, flexible object. Debris (a long, thin flexible piece and two bright objects) appeared near the RH aft booster shortly after liftoff and moved away from the vehicle. The debris appeared to originate near the HDP #4 area (E-52).

Film item E-60 confirmed that water flowed properly from all MLP rainbirds.

A 15-20 inch long piece of thermal curtain tape was loose under the aft skirt near HDP #2 at liftoff (E-1, 2, 5, 8, 9, 31, 212).

Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters and were pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings (E-213).

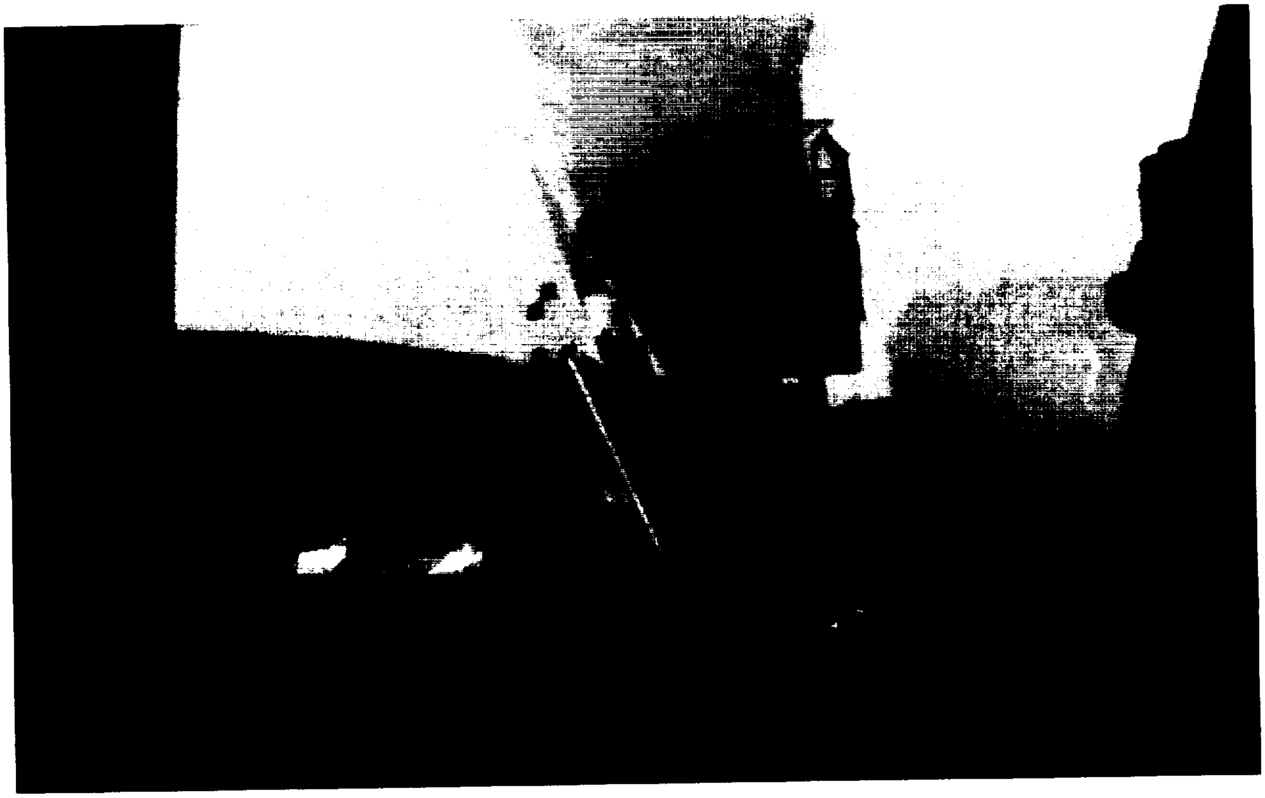
Orange flashes occurred in the SSME plume during ascent at 16:12:53.167 and 16:12:54.636 GMT (E-222).

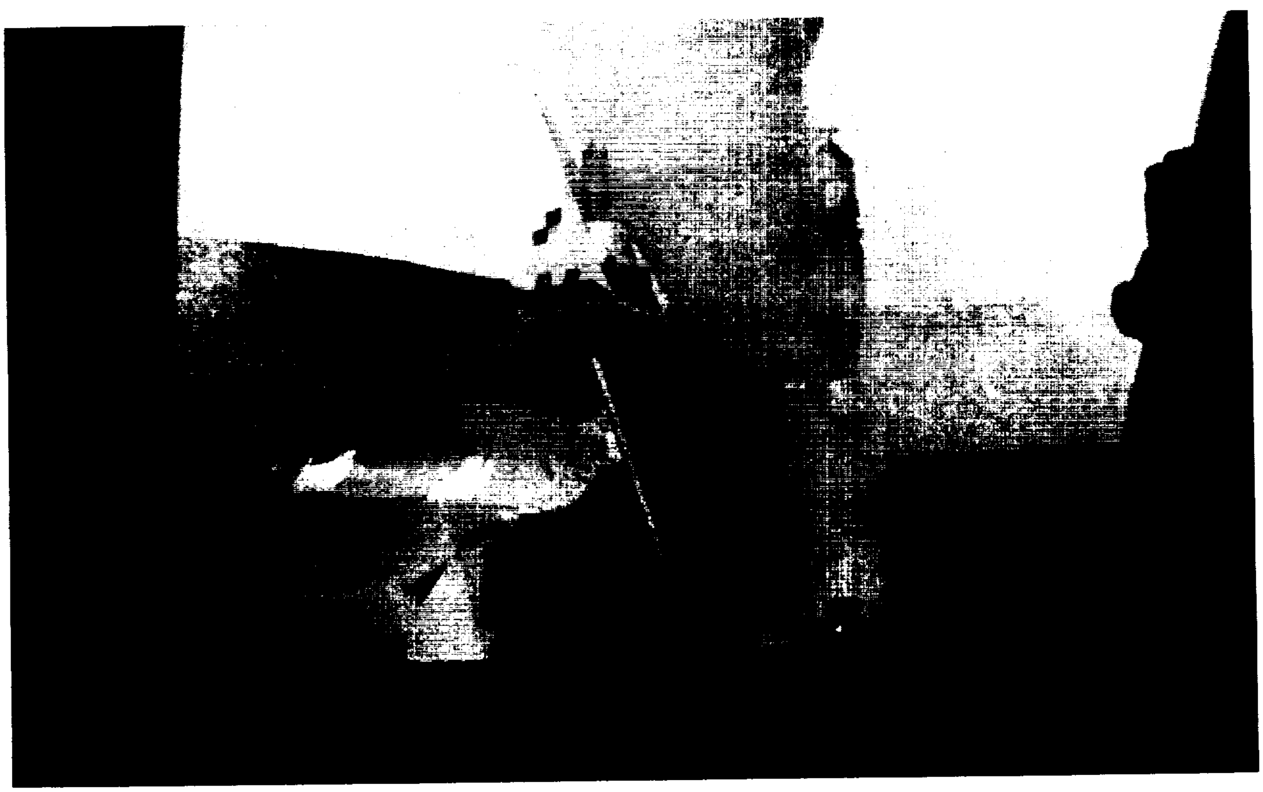
Movement of the body flap was visible (E-220).

Tracker coverage was hindered due to cloud coverage.

ET aft dome charring, plume recirculation, and SRB separation appeared normal. (TV-13).

Frustum separation from the forward skirts, parachute deployment and reefing appeared normal. Nozzle severance debris, which was typical, caused some small tears/damage to the parachutes. Water splashdown was not visible (E-301, 302).





A stud hang-up occurred on HDP #7. The stud remained fully extended as the aft skirt ascended. The stud pulled off a 6"x3" piece of the EPON shim (arrow), "twanged" briefly after clearing the stud hole, and dropped into the holddown post.

A semi-rigid object, possibly a piece of SRB thermal curtain tape or HDP firing line tape, first appeared in the RH SRB exhaust hole near HDP #4, passed between camera E-15 and the center rainbird, and moved north away from the vehicle.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

Separation views of the LH Solid Rocket Booster and External Tank were obtained from one 35mm and two 16mm ET/ORB umbilical cameras. Shortly after ET separation, sunlight saturated the FOV on all three cameras. In addition, there were eighty-nine 70mm still views taken by the flight crew. The first 65 frames were taken while the window UV filter was still mounted in window #8 causing the frames to be underexposed.

Separation of the LH SRB from the ET, and separation of the ET from the Orbiter, appeared nominal.

Approximately 60 percent of the LH bipod ramp closeout was missing to a depth that exposed part of the spindle housing along with some of the intertank acreage foam at the leading edge of the ramp (26" x 10" total damage site). Debris damage to Orbiter TPS was subsequently found to be greater than average, including a 9"x4.5"x0.5" damage site on the lower surface, and may have been caused by the loss of the ET foam. Loss of the bipod ramp closeout could be the result of TPS material failure on the ET intertank acreage due to inadequate venting. This event appeared similar to the occurrence on STS-7.

IFA STS-50-I-01 was taken, and as a result, additional vent holes were drilled around the ET-48 (STS-46), ET-45 (STS-47), and ET-49 (STS-53) bipod ramp closeouts. The vent holes relieve any possible trapped gas pockets in foam-over-foam ET intertank TPS.

The RH jack pad closeout and some adjacent foam was missing (6 inch diameter divot). The LH jack pad closeout was intact.

Numerous areas of TPS erosion and small divots occurred on the thrust strut flange closeouts, the LO2 feedline flange closeouts, six of the pressurization line ramps, and two of the cable tray ice/frost ramps. A 7-inch diameter divot occurred on the inboard side of the LO2 feedline support bracket at XT-1377.

Small divots and TPS erosion occurred on the LH2 ET/ORB umbilical support bracket and cable tray. No TPS damage occurred on the umbilical though frozen hydrogen was visible on the flapper valve and along the seal.

Small divots and TPS erosion occurred on the LO2 ET/ORB umbilical cable tray (horizontal section). Six divots, including one that spanned the entire width of the cable tray, were present on the +Z side of the vertical section.

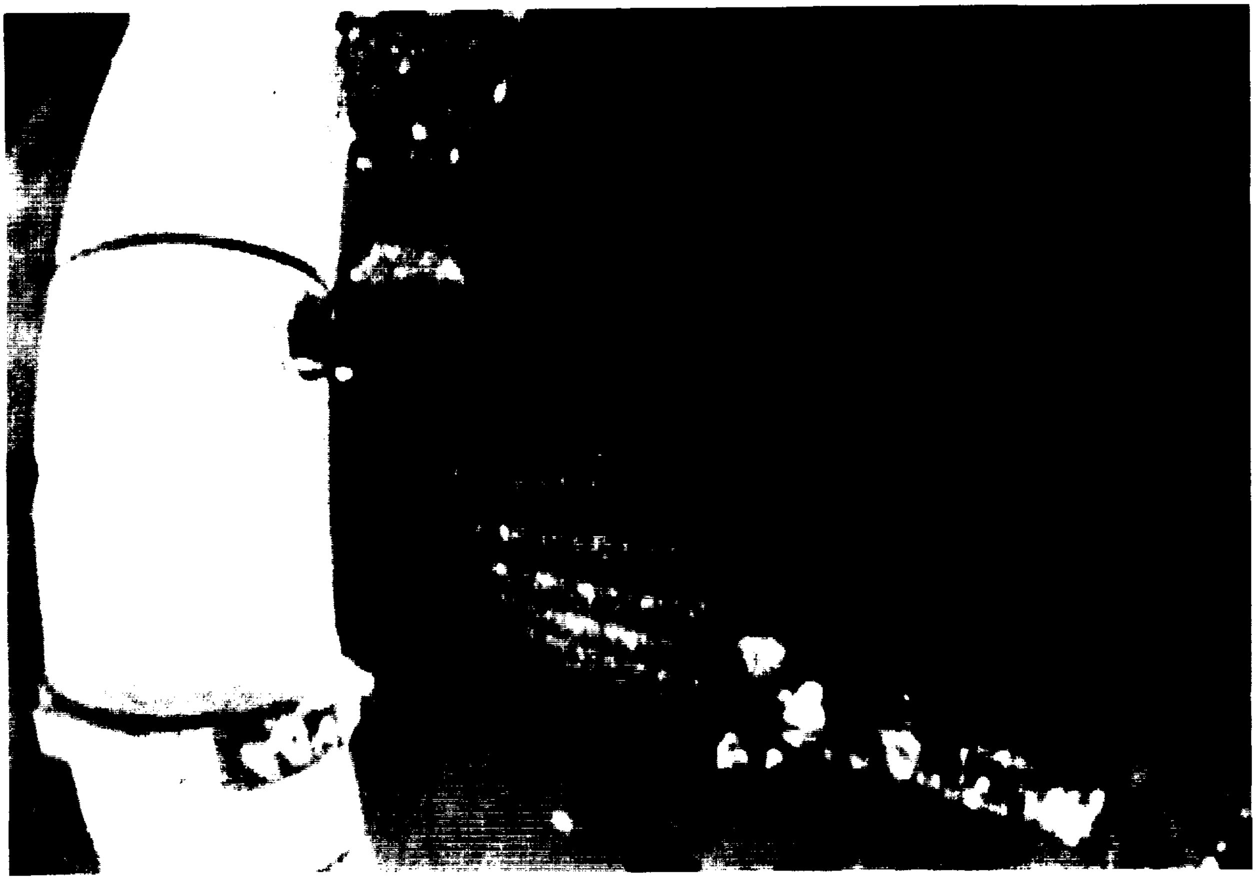
Charring and erosion of the -Y vertical strut aft surface and "popcorning" of the aft dome NCFI were typical.

There were no apparent anomalies on the LO2 tank, LH2 tank, and aft dome TPS acreage. The BSM burn scars were typical. The nosecone, intertank access door, GH2 umbilical carrier plate, ET/SRB forward attach points, and RSS antennae were in nominal configuration.

5.3 LANDING FILM AND VIDEO SUMMARY

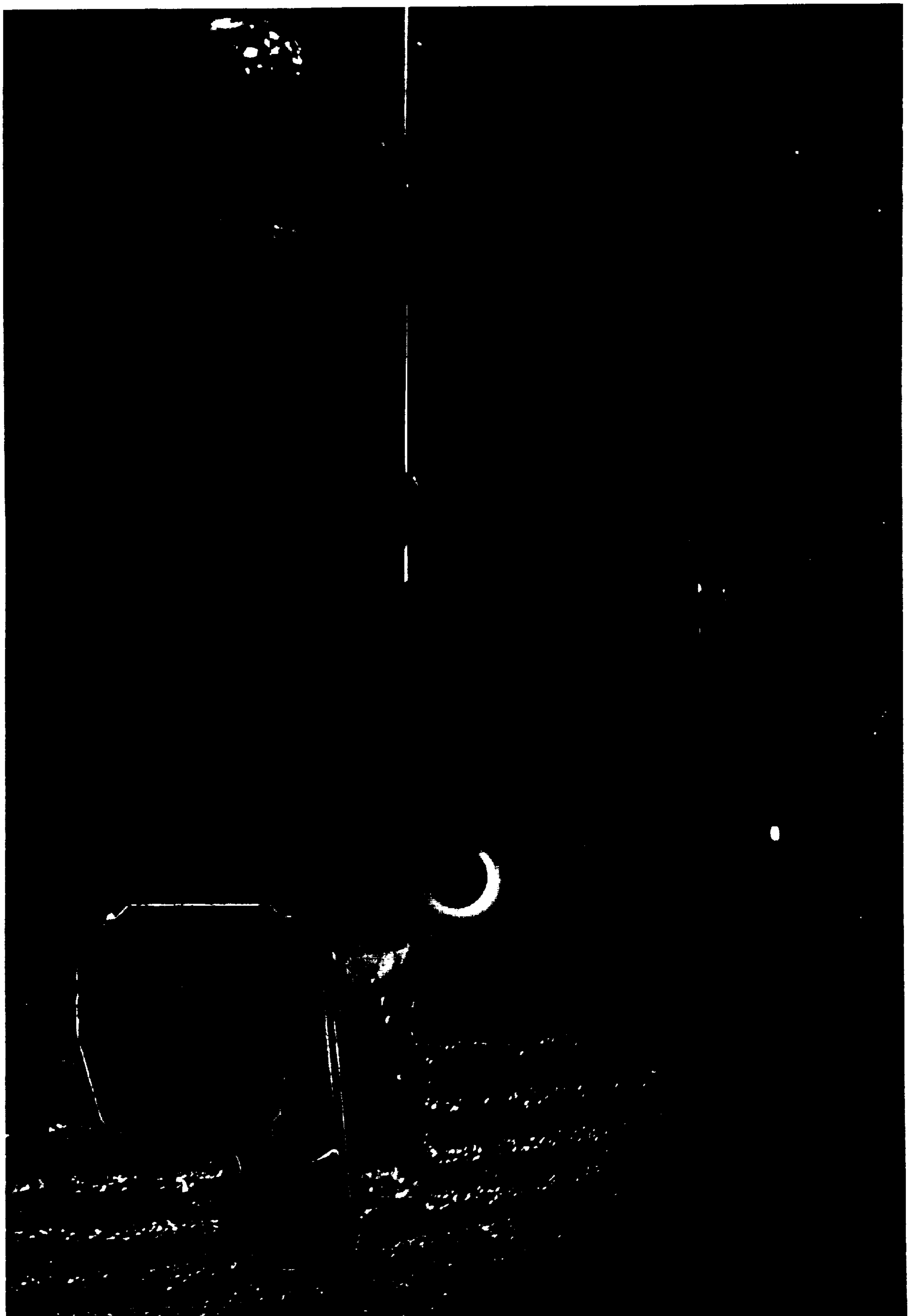
A total of seventeen film and video data items, which included seven videos, six 16mm high speed films, and four 35mm large format films, were reviewed.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. Main landing gear deployment and touchdown was normal. Nose rotation and touchdown of the nose landing gear was smooth. First use of the drag chute for a KSC landing appeared normal. No vehicle or major tile damage was visible in these views.

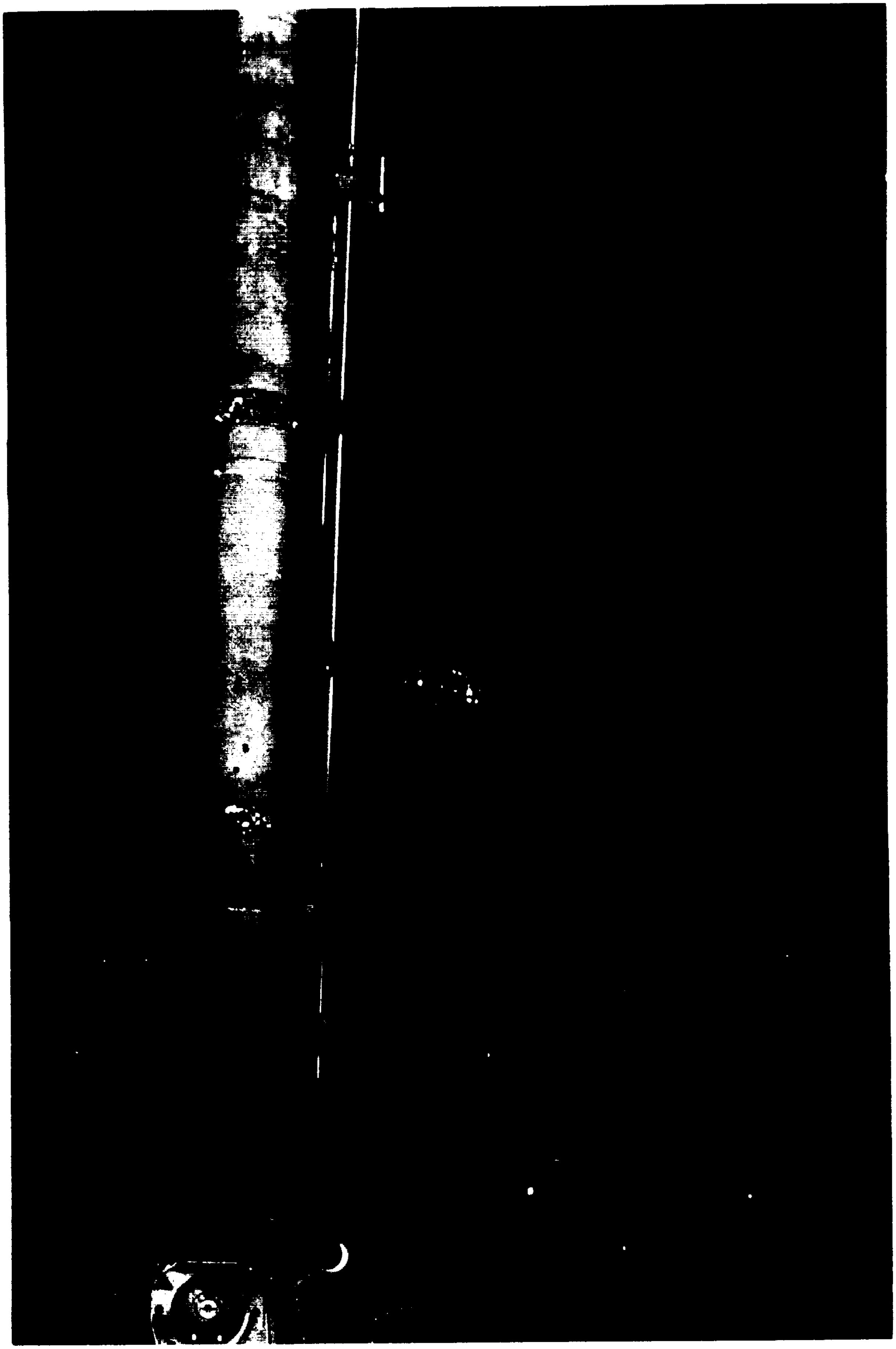


LH2 ET/ORB umbilical separation camera with 5mm lens showed no vehicle damage or loss of flight hardware that would have been a safety of flight concern. Separation of the LH SRB from the External Tank was nominal.

LH2 ET/ORB umbilical separation camera with 10mm lens showed typical erosion and charring of TPS on the aft surfaces of the umbilical cable tray and -Y vertical strut. Plume recirculation and aft dome heating caused the usual charring and "popcorning" of the NCFI foam. Small divots and TPS erosion occurred on the LH2 ET/ORB umbilical support bracket and cable tray. No TPS damage occurred at the umbilical interface though frozen hydrogen was visible on the flapper valve and along the seal.



Numerous areas of TPS erosion and small divots occurred on the LO2 feedline support bracket and flange closeout, pressurization line ramp, and ET/SRB cable tray closeout. Six divots, including one that spanned the entire width of the cable tray, were present on the LO2 ET/ORB umbilical.



Numerous areas of TPS erosion and small divots occurred on the thrust strut flange closeout, the cable tray ramp, the press line ramps, and the LO2 feedline flange closeouts and support bracket.

A 26"x10" area of LH bipod ramp closeout, along with a portion of the intertank TPS acreage, was missing. In addition, the RH bipod jack pad closeout was missing. There were numerous divots and areas of missing TPS on the LO2 feedline flange closeouts, support bracket at XT-1377, and pressurization line ramps.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 27 June 1992 from 0930 to 1200 hours. From a debris standpoint, both SRB's were in excellent condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS but had 26 MSA-2 debonds over fasteners (Figure 4). Minor localized blistering of the Hypalon paint had occurred along the 395 ring. All BSM aero heatshield covers were locked in the fully opened position.

The RH forward skirt exhibited no debonds or missing TPS (Figure 5). The -Z RSS antenna was undamaged. Ablator on the +Z RSS antenna cover was significantly eroded, which may have been caused by contact with the tow rope. The top two layers on the phenolic base plate were missing/delaminated. Minor blistering of the Hypalon paint occurred on the systems tunnel cover. No pins were missing from the frustum severance ring. The forward separation bolt and electrical cables appeared to have separated cleanly.

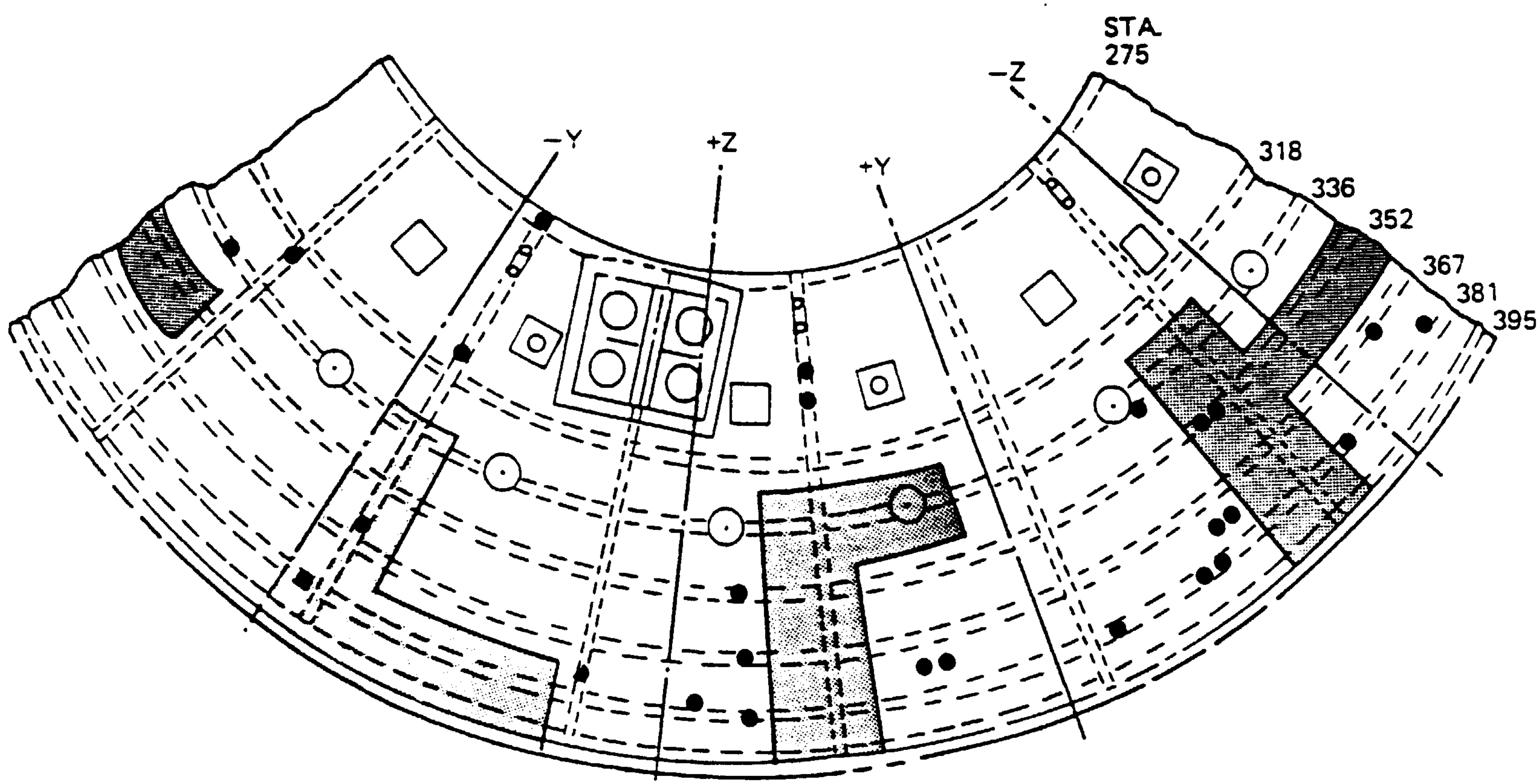
The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. No TPS was missing from the ET/SRB upper strut fairing. All three aft booster stiffener rings sustained water impact damage. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring had delaminated. Eight K5NA protective domes were lost from bolt heads on the aft side of the kick ring prior to water impact (sooted substrate). The aft skirt acreage TPS generally was in good condition. Two TPS divots (2.5"x1", 3"x1.25") were present on the +Y axis of the aft skirt near the aft ring (XB-1926). Since sooting/charring was evident on the edges of the divots, the surrounding material was removed for further analysis. K5NA was missing from all aft BSM nozzles (Figure 6).

The HDP #4 stud hole was broached due to a stud hang-up at lift off as observed in the launch films. A 6"x3" piece of the EPON shim material had been pulled off by the stud. A small piece of the HDP #3 EPON shim was missing prior to water impact (sooted/ charred substrate). All Debris Containment System (DCS) plungers were seated properly. This was the eighth flight utilizing the optimized link.

Figure 4. **RIGHT SRB FRUSTUM**



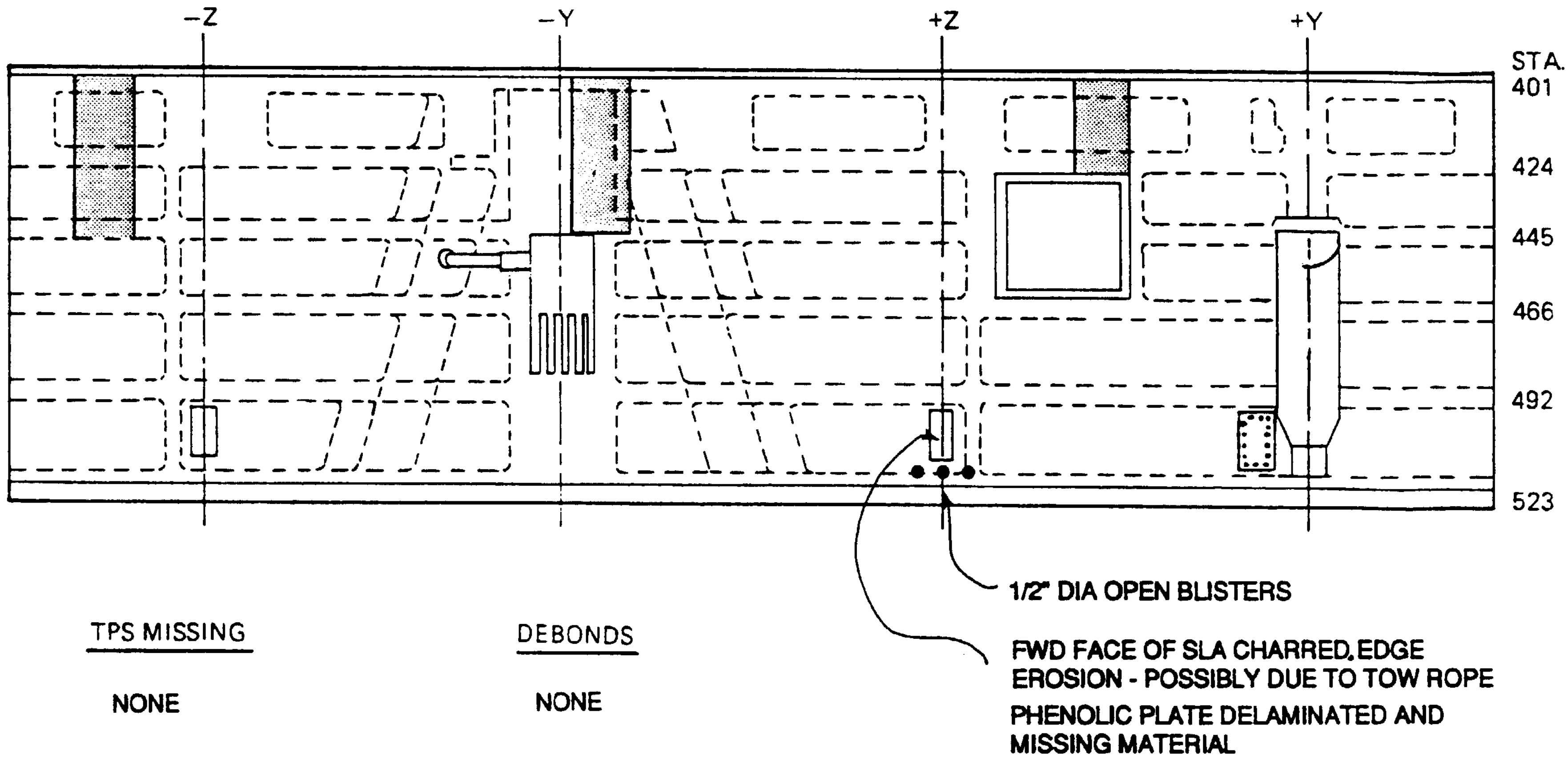
MISSING TPS

NONE

DEBONDS

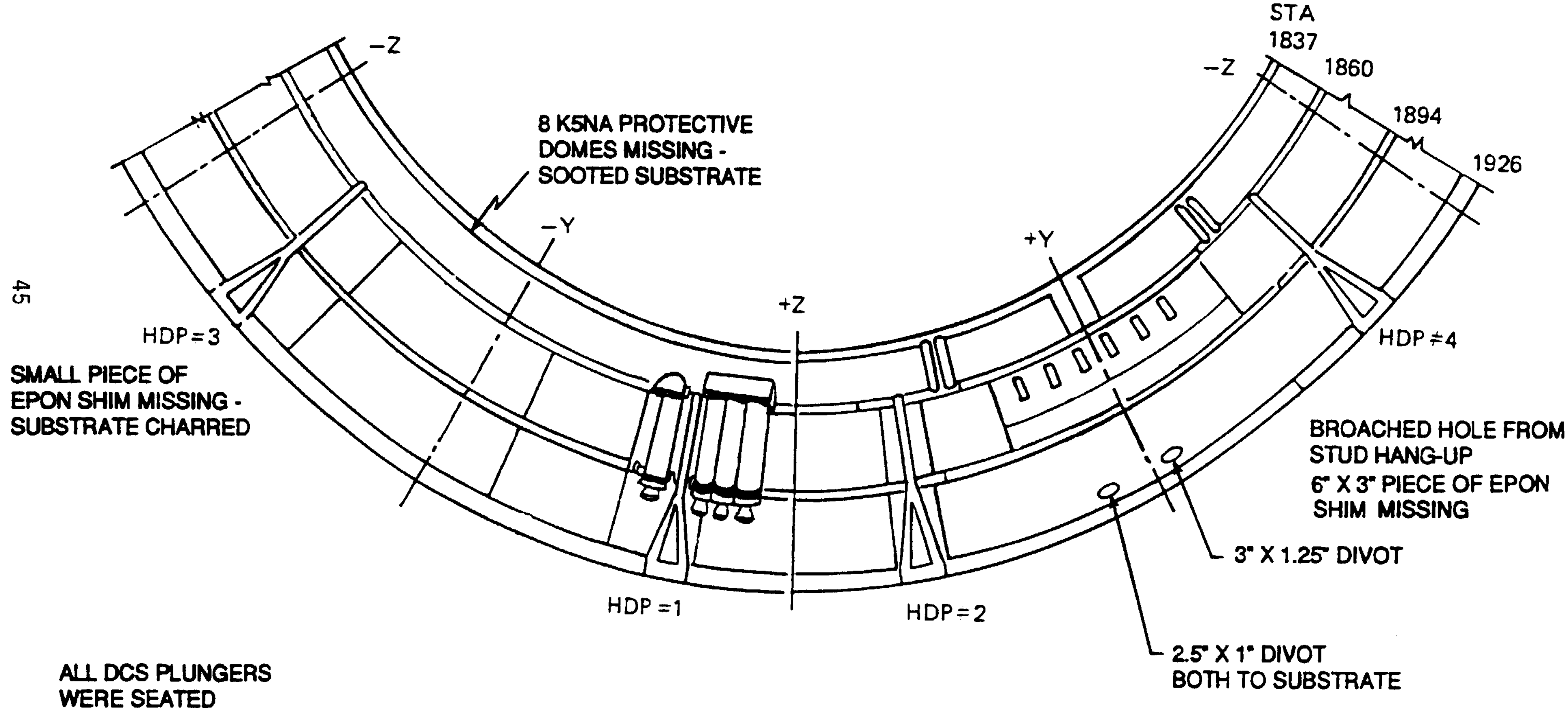
● 26

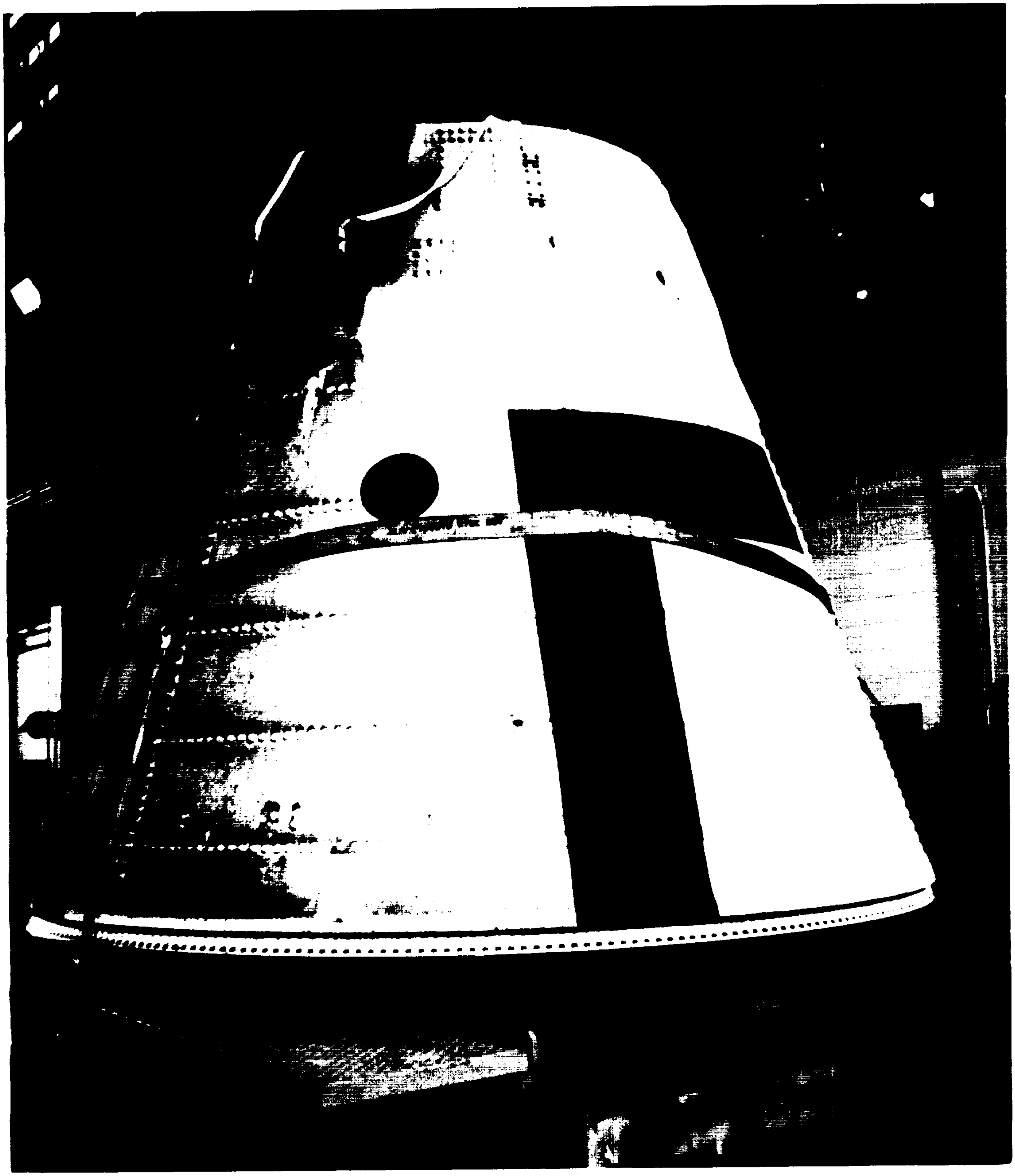
Figure 5. **RIGHT SRB FWD SKIRT**



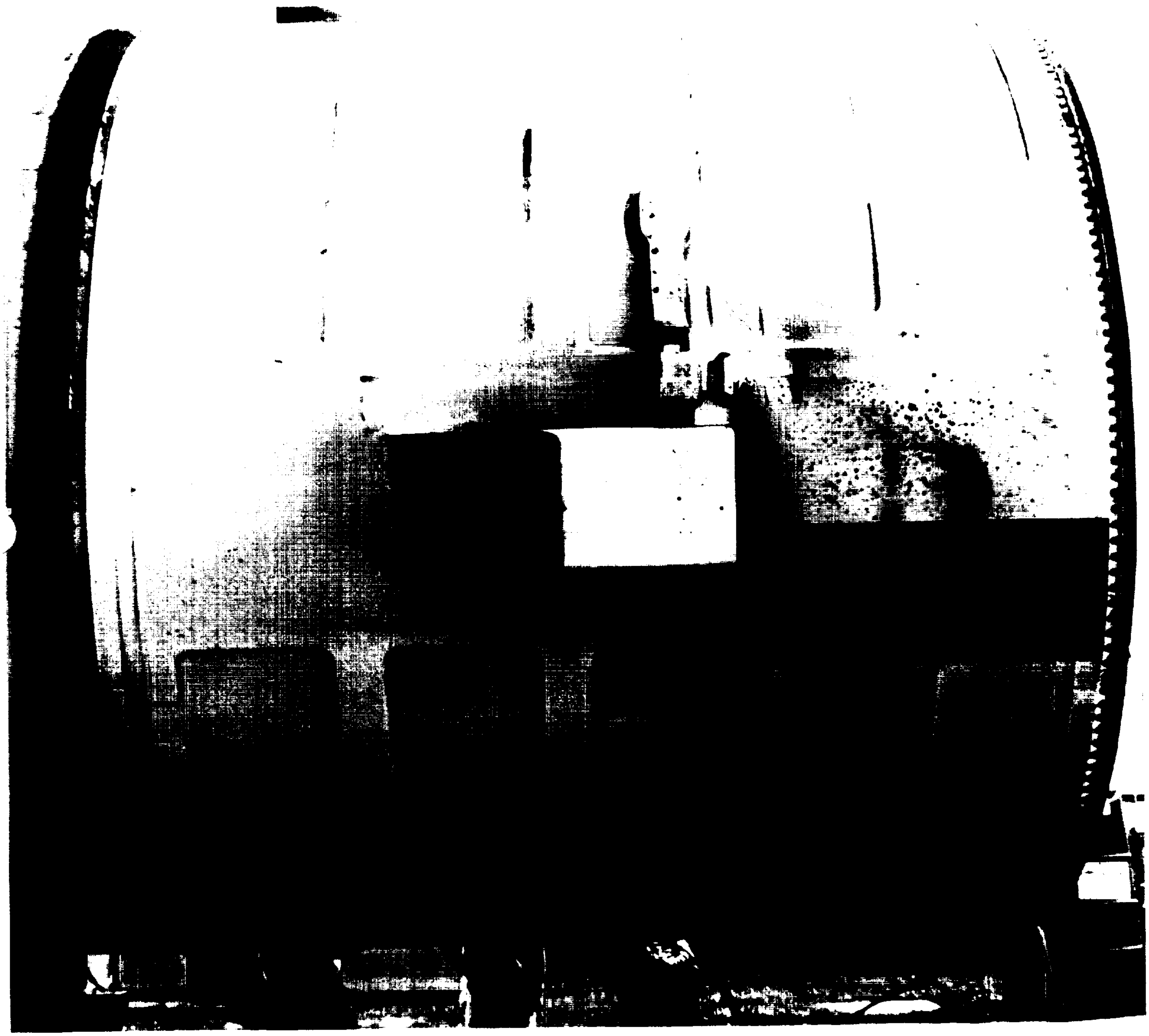
EGG/V 326A

Figure 6. **RIGHT SRB AFT SKIRT EXTERIOR TPS**

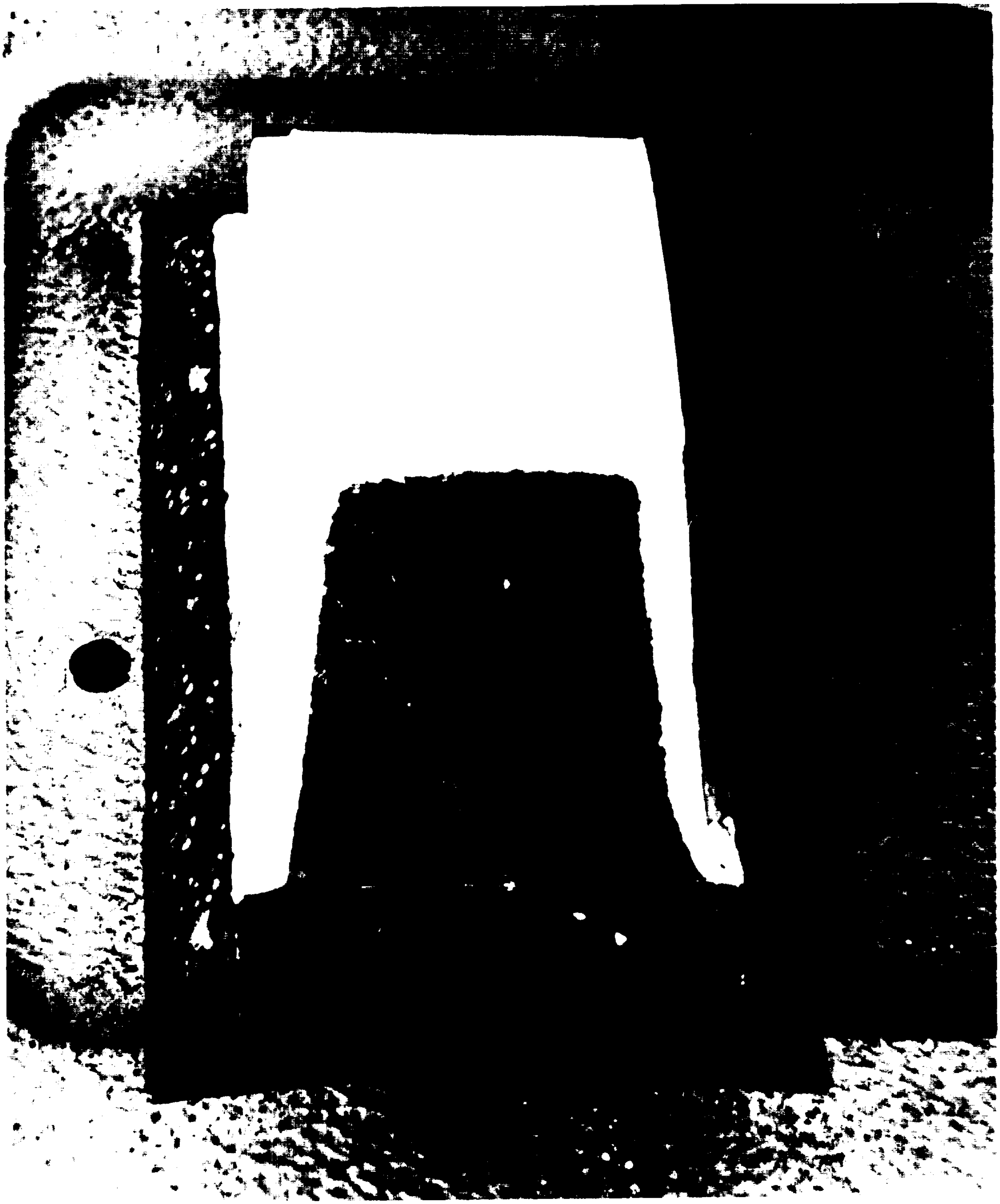




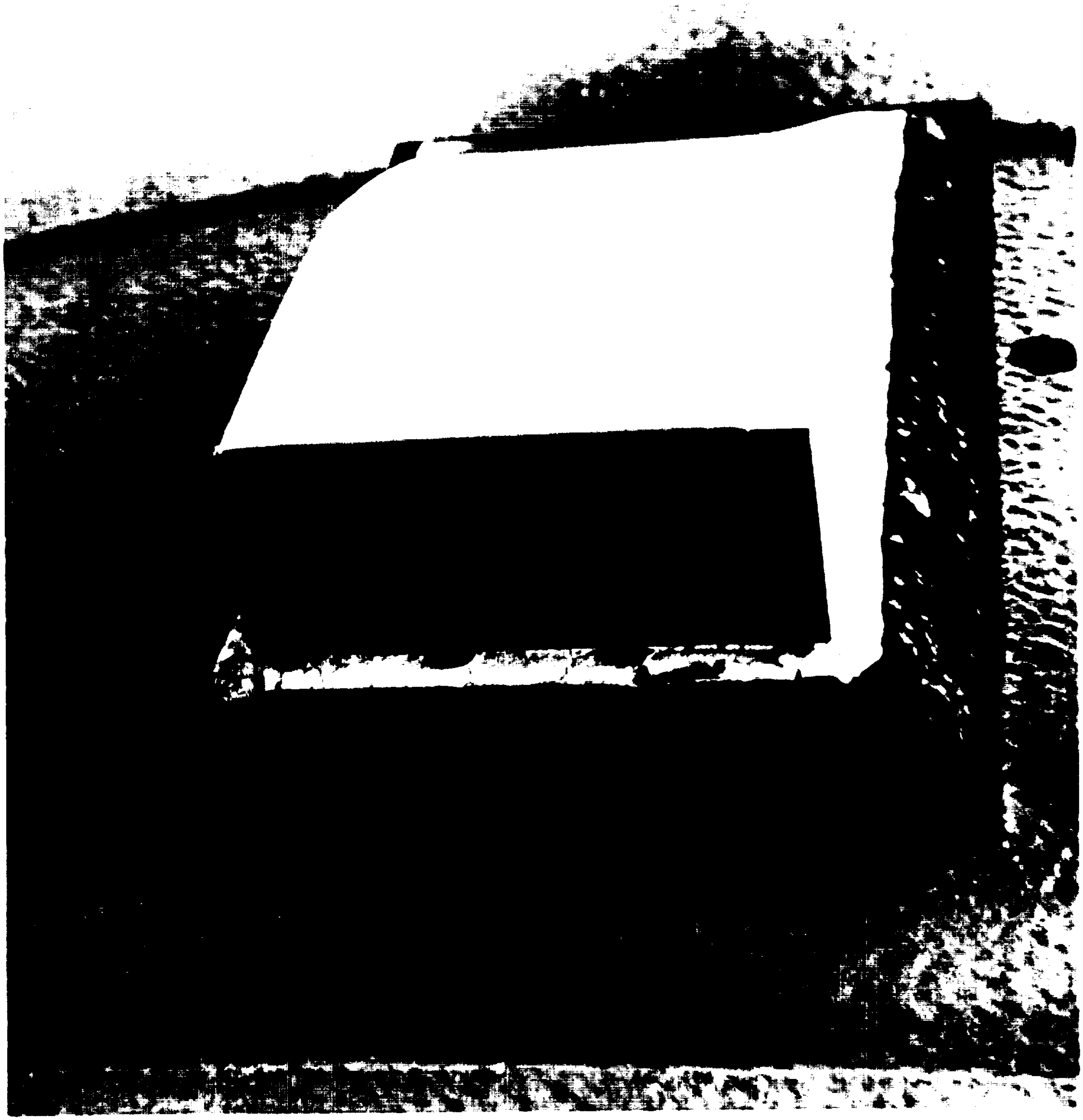
The RH frustum was missing no TPS but had 26 MSA-2 debonds over fasteners. Minor blistering of the Hypalon paint had occurred along the 395 ring. The BSM aero heat shield covers were locked in the fully opened position.



The RH forward skirt exhibited no debonds or missing TPS. Minor blistering of the Hypalon paint occurred in localized areas.



Ablator on the +Z RSS antenna cover was significantly eroded, but the clean edges indicated the loss of material had been caused by contact with the tow rope.



The top two layers of the +Z RSS antenna
phenolic base plate were missing/delaminated

Post flight condition of the RH aft booster. The aft skirt acreage TPS was sooted but in good condition. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage.

The HDP #4 stud hole was broached due to a stud hang-up at lift off. A 6"x3" piece of the EPON shim material had been pulled off by the stud.

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum had 15 MSA-2 debonds over fasteners and was missing MSA-2 (2.5"x1.5" maximum) from one location near the -Z axis. There was minor localized blistering of the Hypalon paint (Figure 7). The BSM aero heatshield covers were locked in the fully opened position. However, two RH cover attach rings had been bent at the hinge by parachute riser entanglement.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact. However, most of the ablator on the +Z antenna cover was lost at water impact (clean substrate) and was not a debris concern (Figure 8). The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred near the ET/SRB attach point and on the systems tunnel cover.

The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension. A 3/8"x1/8" piece of slag was embedded in the aft side of the forward field joint K5NA closeout at 140 degrees. Three divots to substrate (2.8"x2.0" at 180 degrees; 2.6"x2.0" at 186 degrees; 3.0"x2.0" at 192 degrees) were present in the forward center segment GEI cork closeout at XB-1099 near the -Z axis away from the Orbiter. One of the divots was sooted on the forward edge of the material. Since additional unbonds were found adjacent to the missing material, the remaining cork was removed for further analysis.

Separation of the aft ET/SRB struts appeared normal. All three aft booster stiffener rings, the upper strut fairing, a section of the ETA ring/IEA sustained water impact damage. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring had delaminated. Some K5NA protective domes were missing from bolt heads on the aft side of the phenolic kick ring prior to water impact (charred substrate). The aft skirt acreage TPS was generally in good condition with the exception of two divots measuring 4"x3" and 3"x2" located between the single BSM and the +Y axis at XB-1860. Sooting pattern showed time of occurrence to be descent. K5NA was missing from all aft BSM nozzles (Figure 9).

All four Debris Containment System (DCS) plungers were properly seated. This was the eighth flight utilizing the optimized link. None of the EPON shim material was lost prior to water impact.

Figure 7. **LEFT SRB FRUSTUM**

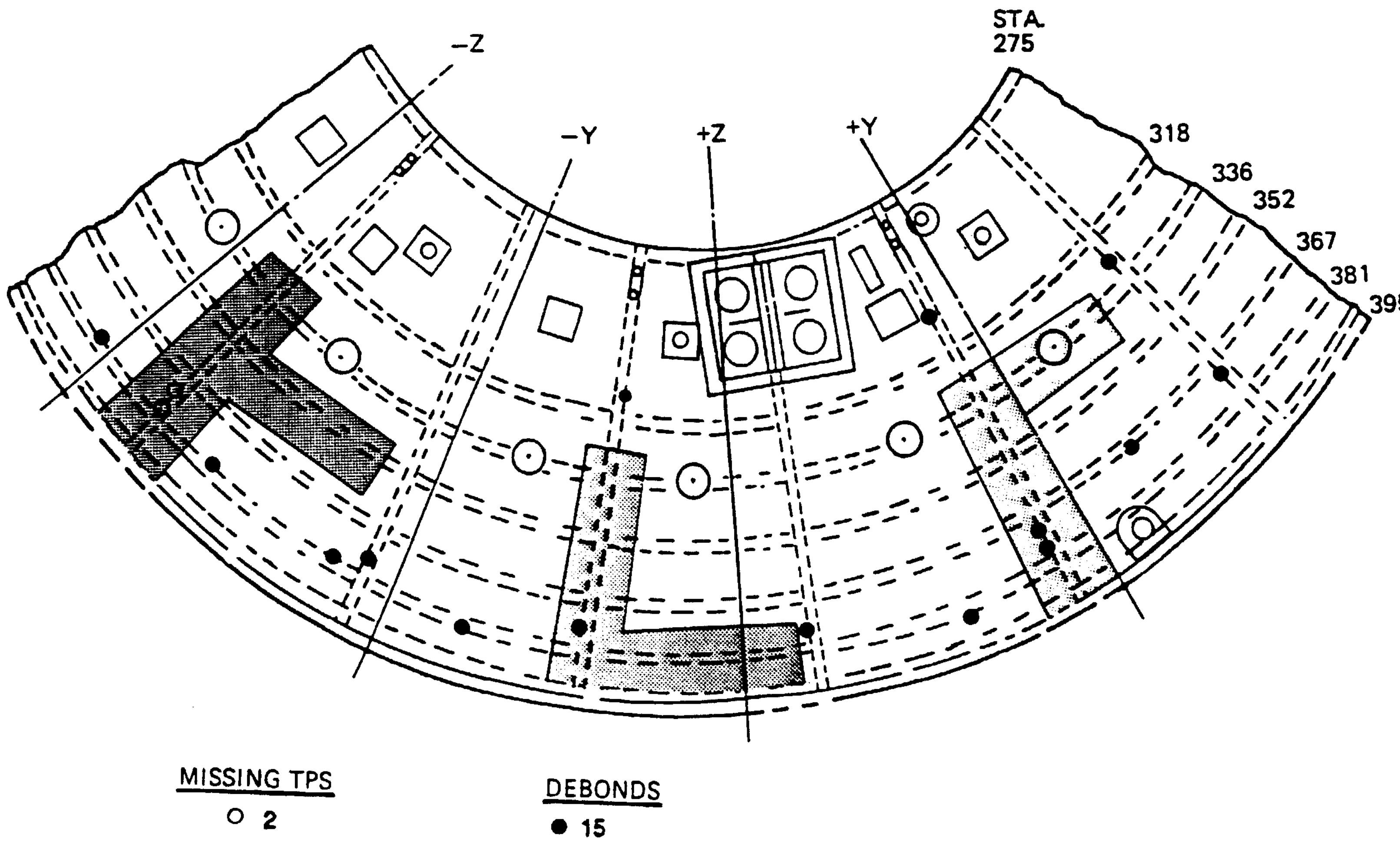
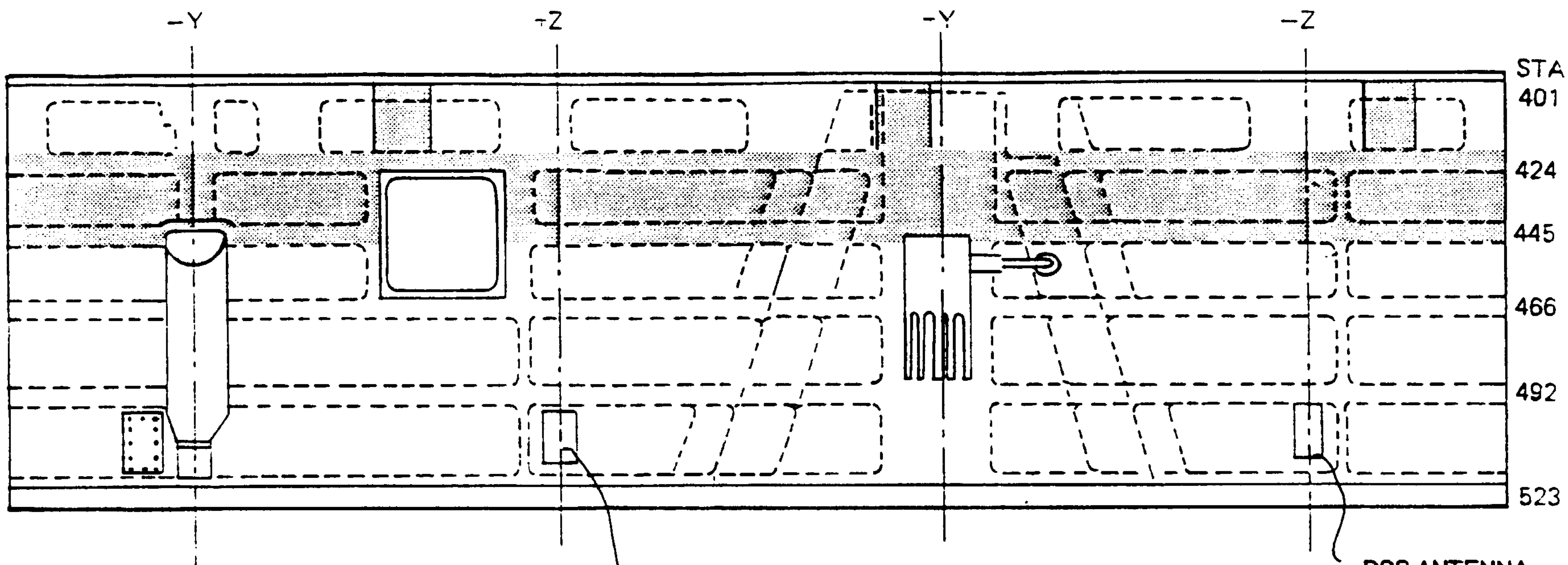
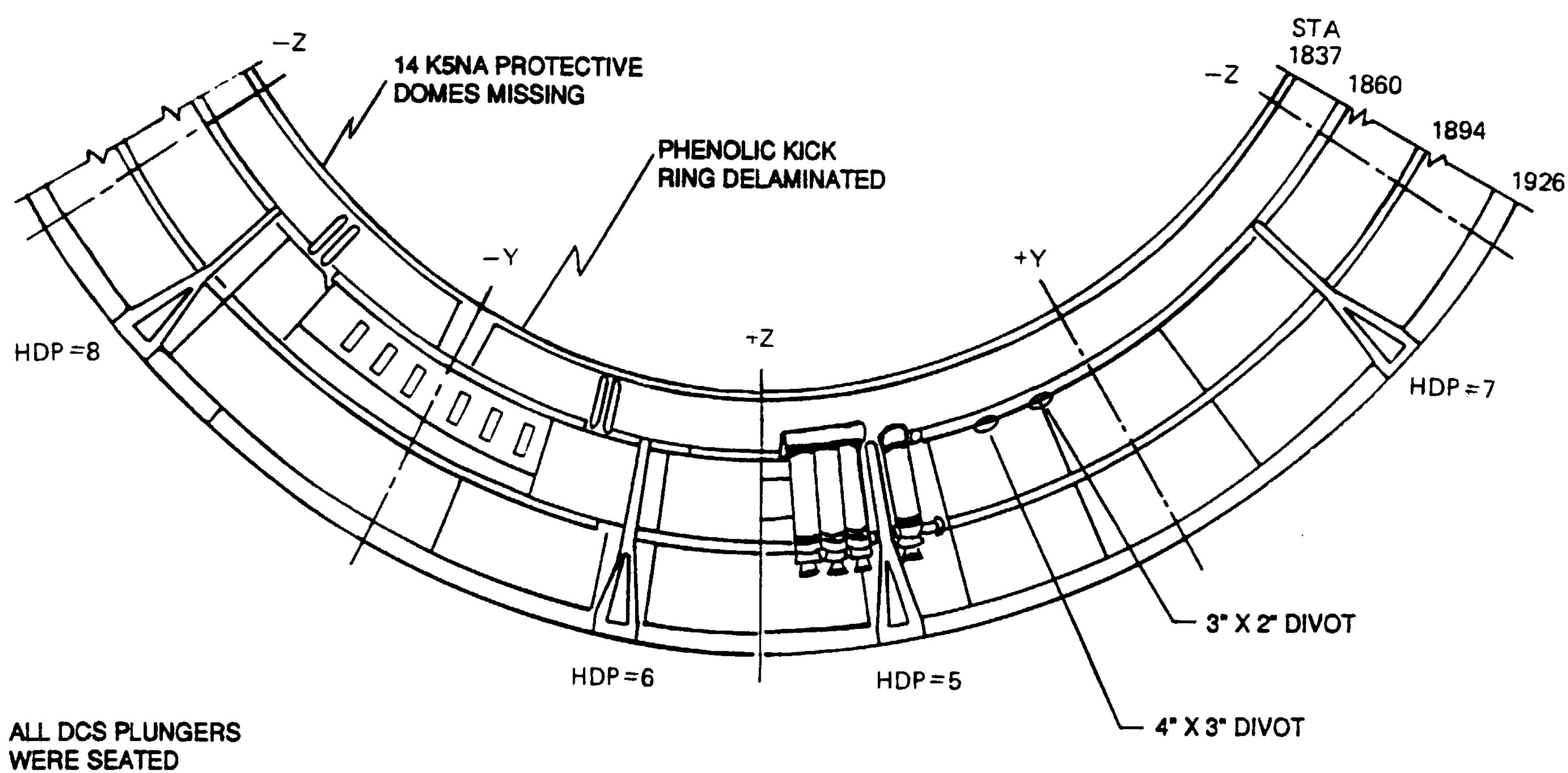


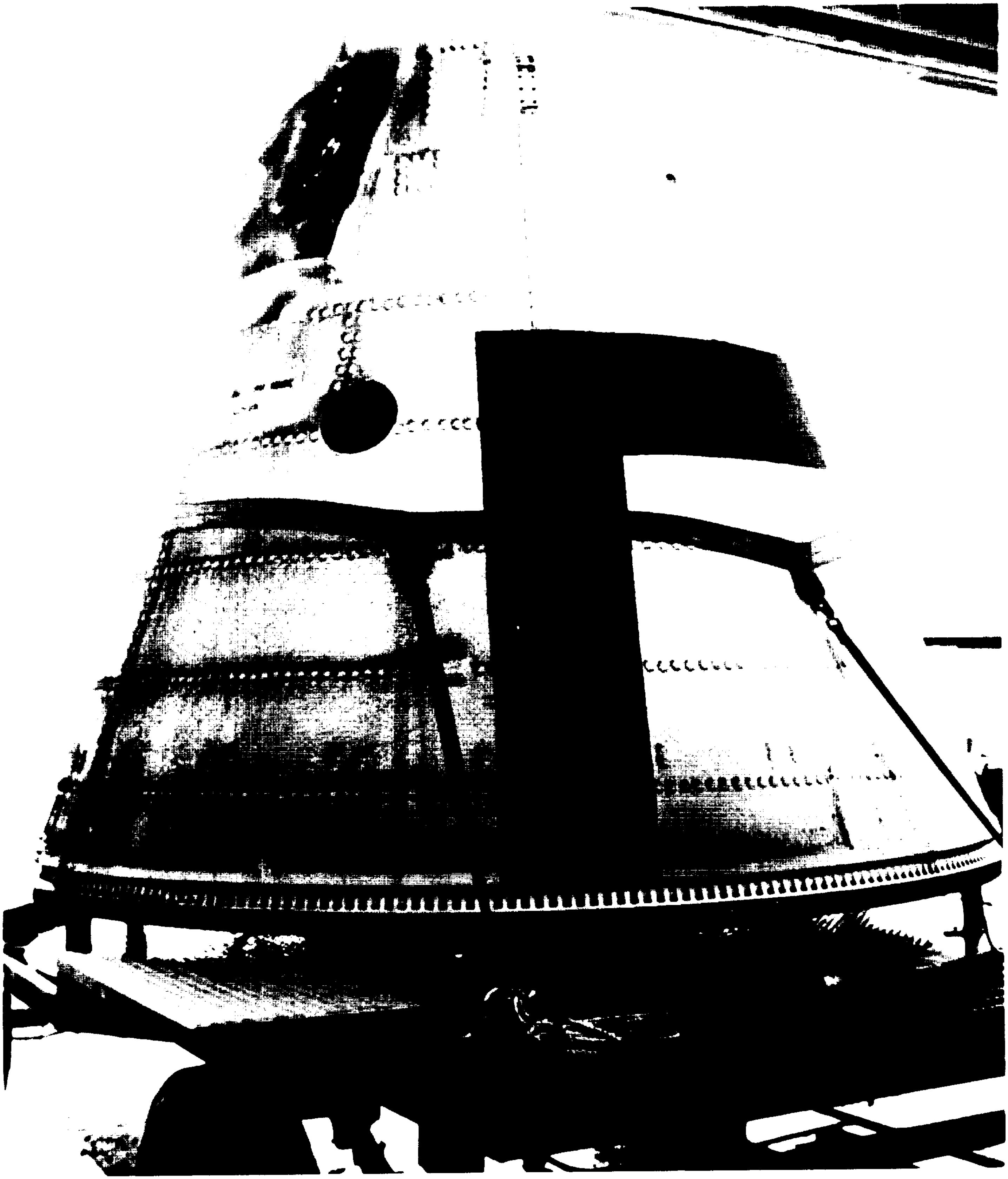
Figure 8. **LEFT SRB FWD SKIRT**



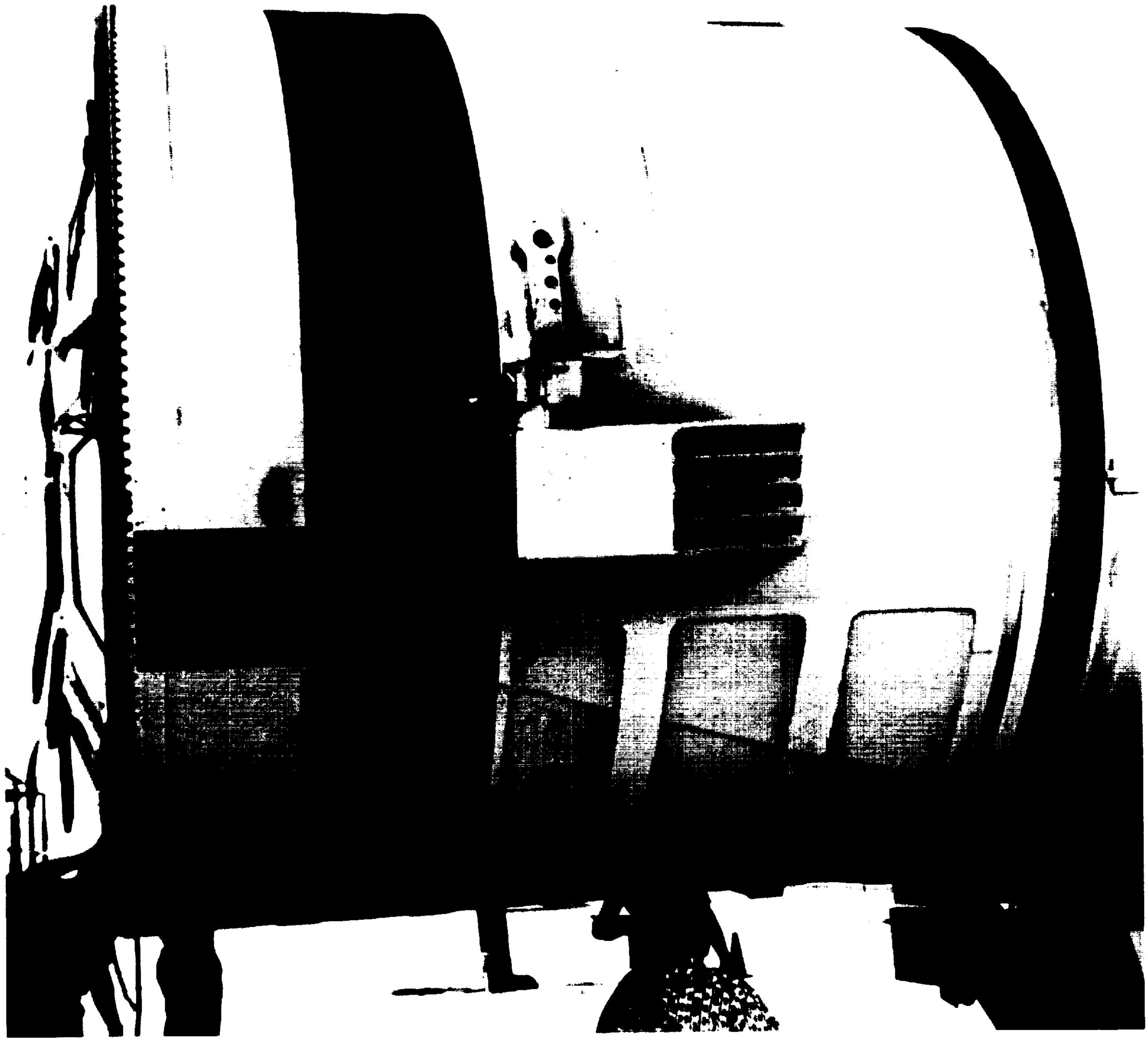
TPS MISSING	DEBONDS
NONE	NONE

Figure 9. **LEFT SRB AFT SKIRT EXTERIOR TPS**





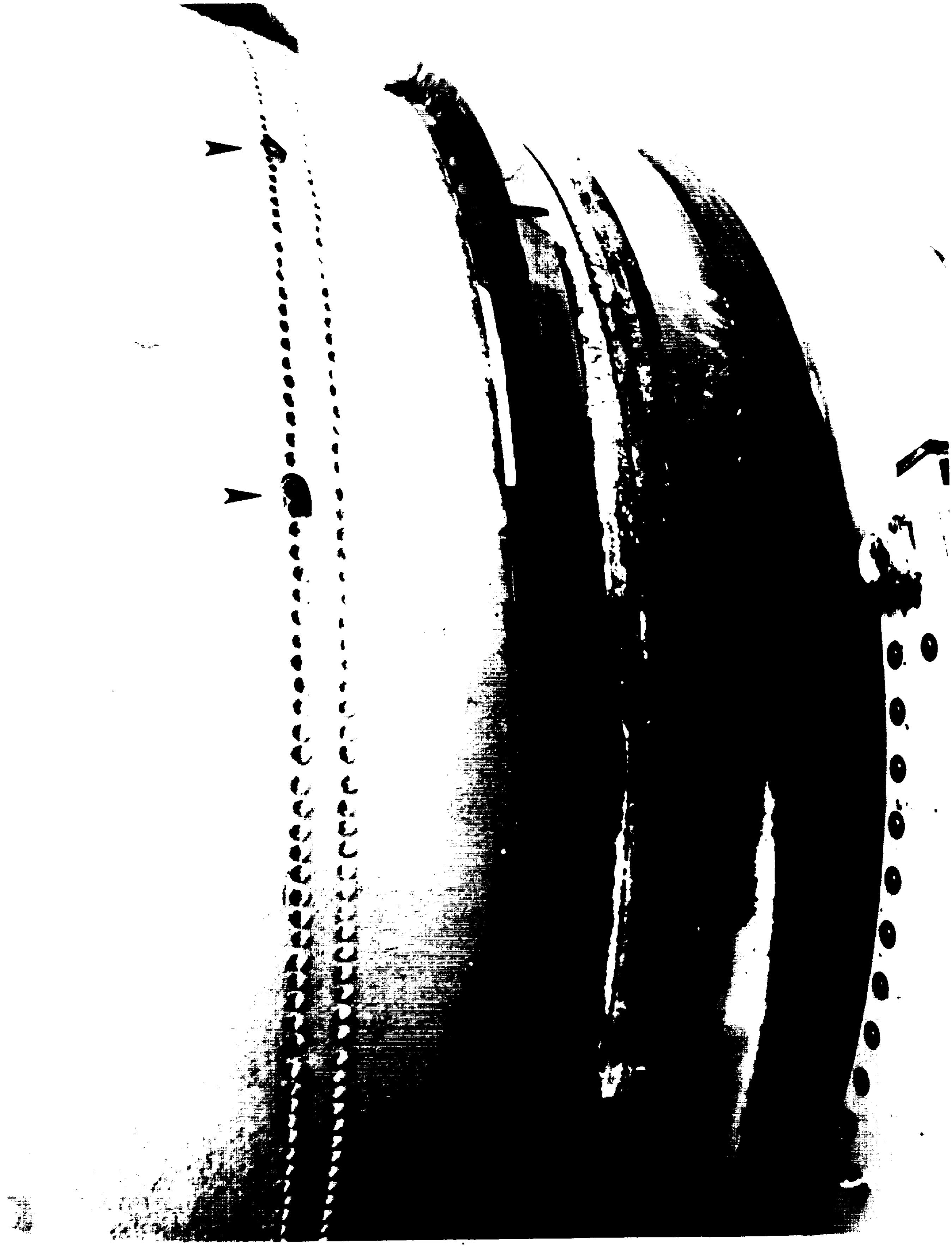
The LH frustum had 15 MSA-2 debonds over fasteners and was missing MSA-2 from one location near the -Z axis. There was minor localized blistering of the Hypalon paint. The BSM aero heat shield covers were locked in the fully opened position, but the two RH cover attach rings had been bent at the hinge by parachute riser entanglement.



The LH forward skirt exhibited no MSA-2 debonds or missing TPS.

The phenolic plates on both RSS antennae were intact. However, most of the ablator on the +Z antenna cover was lost at water impact (clean substrate) and was not a debris concern.

Three divots to substrate were present in the forward center segment GEI cork closeout at XB-1099 near the -Z axis away from the Orbiter. One of the divots was sooted at the forward edge of the material. Post flight assessment revealed an adhesive failure between the EA934 and the paint. The application procedure was subsequently modified.



K5NA protective domes were missing from the aft side of the phenolic kick ring prior to water impact (sooted substrate). Two divots occurred in the aft skirt acreage TPS between the single BSM and the +Y axis. The sooting pattern indicated the loss of material occurred during re-entry.

COLOR PHOTOGRAPH

6.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 99 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	99	88	97
2	99	98	99
3	99	94	99
4	99	94	99
5	99	95	99
6	99	95	99
7	99	94	99
8	99	94	99

STS-50 was the eighth flight to utilize the new "optimized" frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from falling out of the DCS yet not increase the likelihood of a stud hang-up. According to NSTS-07700, the Debris Containment System should retain a minimum of 90 percent of the ordnance debris.

Post flight assessment on the loss of cork material from the LH forward center segment GEI closeout revealed an adhesive failure between the EA934 and the paint. The problem was traced to application/technique. PR PV6-222762 was elevated to IFA STS-50-M-01.

SRB Post Launch Anomalies are listed in Section 9.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing inspection of OV-102 (Columbia) was conducted on 9-10 July 1992 at the Kennedy Space Center on Shuttle Landing Facility (SLF) Runway 33 and in the Orbiter Processing Facility (OPF) to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 184 hits, of which 45 had a major dimension of one inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 32 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42 which had damage from known debris sources), indicates that the total number of hits is higher than average and the number of hits one inch or greater is much higher than average. Figures 10-13 show the TPS debris damage assessment for STS-50.

The Orbiter lower surface sustained a total of 141 hits, of which 28 had a major dimension of one inch or larger. The most significant tile damage measured 9"x4.5"x0.5", spanned three tiles, and was located approximately 3 feet outboard of the LH2 ET/ORB umbilical. The size and depth is indicative of an impact by a low density material, such as ET TPS foam, and was most likely caused by the loss of the -Y bipod ramp closeout in flight.

A significant concentration of hits greater than one inch (11 total) were present on the middle one-third of the RH wing. This concentration of hits may have been caused by ice and TPS foam from the LO2 feedline bellows, support brackets, and flange closeouts. The distribution of the remainder of the hits on the lower surface does not point to a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

The following table breaks down the STS-50 Orbiter debris damage by area:

	Hits > 1"	Total Hits
Lower Surface	28	141
Upper Surface	1	11
Right Side	10	20
Left Side	2	7
RH OMS Pod	0	0
LH OMS Pod	4	5
Totals	45	184

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in good condition with less than expected wear for a heavy Orbiter weight and a KSC runway landing.

Figure 10. **DEBRIS DAMAGE LOCATIONS**

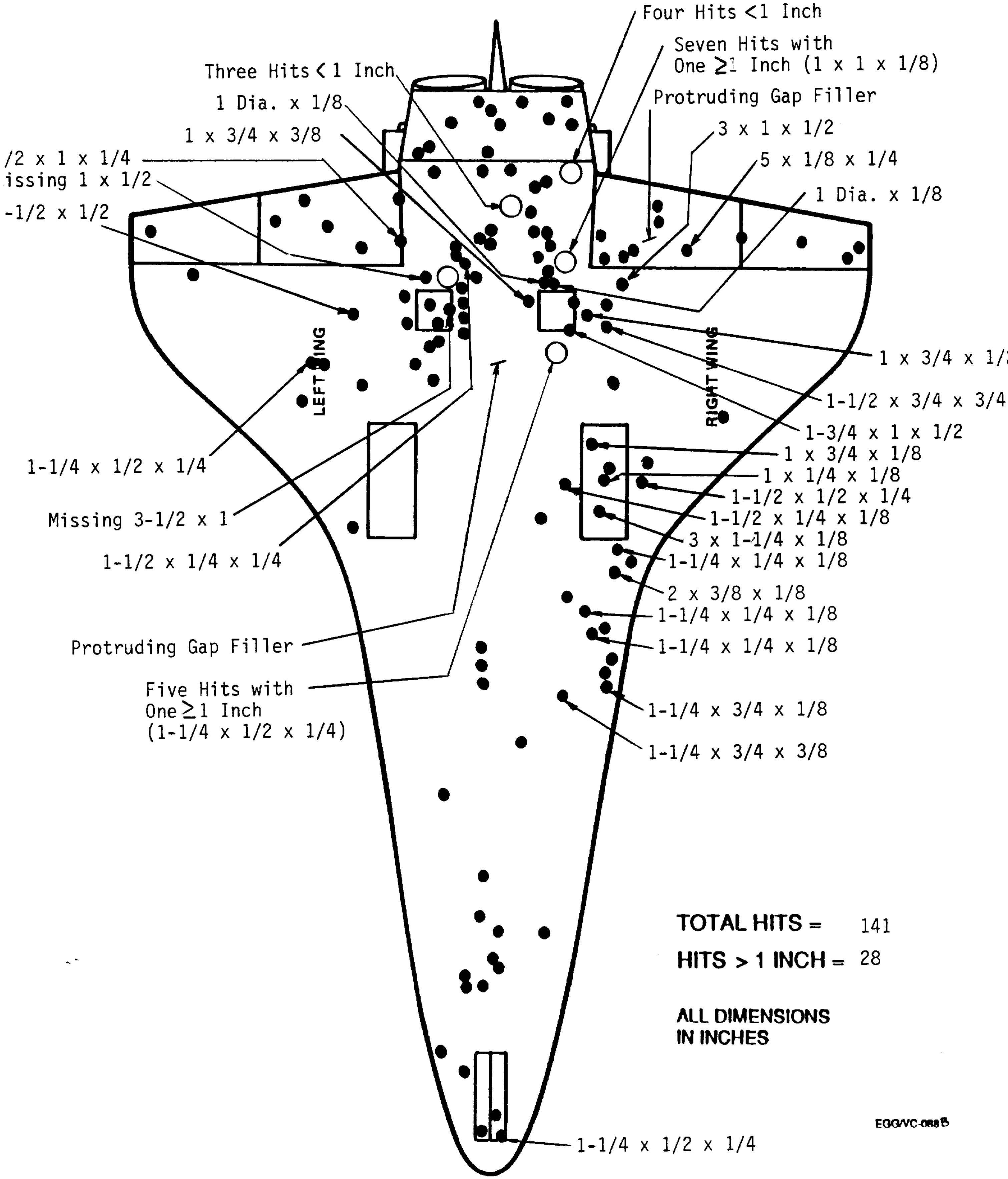
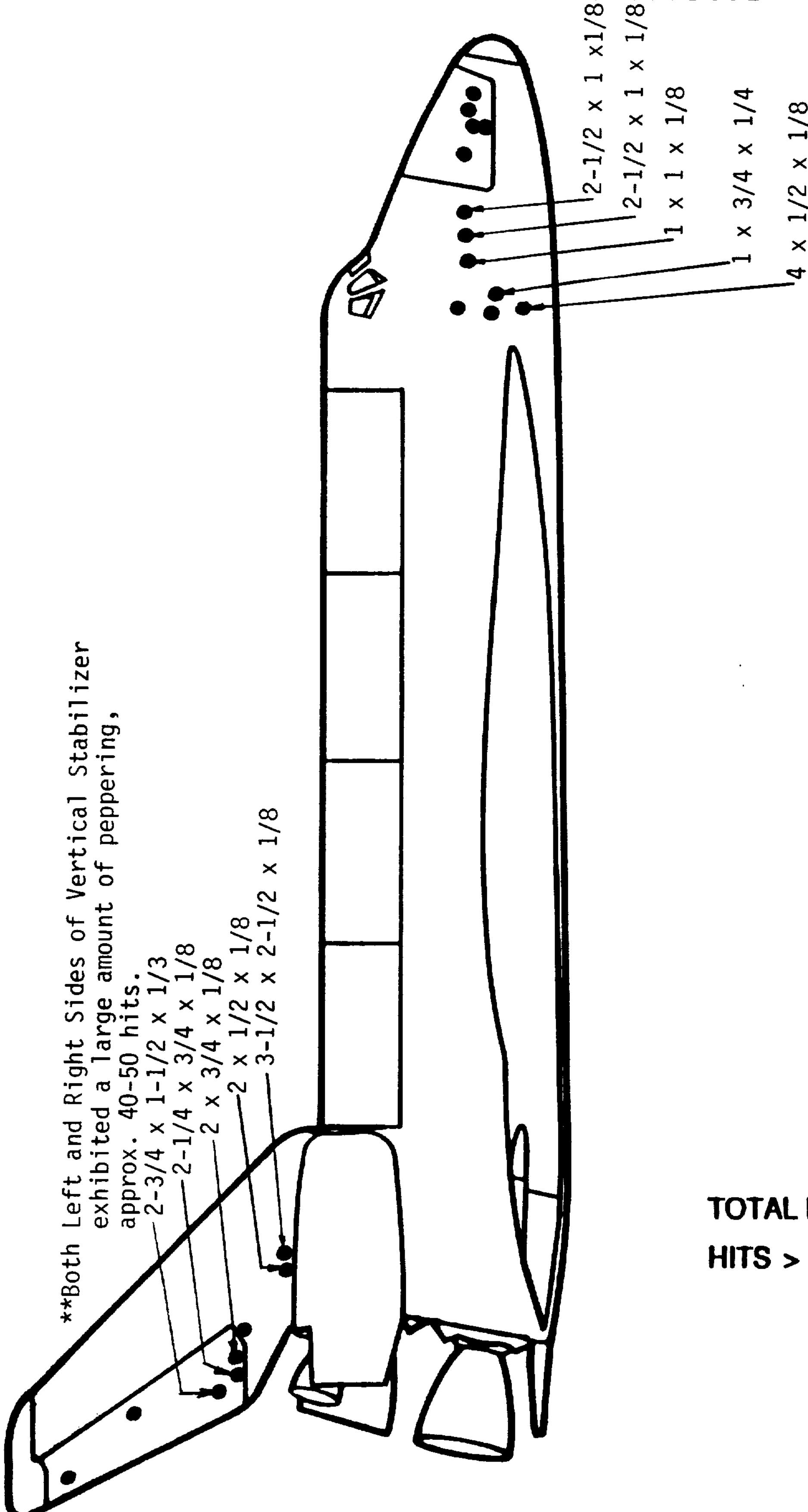


Figure 11. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 20

HITS > 1 INCH = 10

Figure 12. **DEBRIS DAMAGE LOCATIONS**

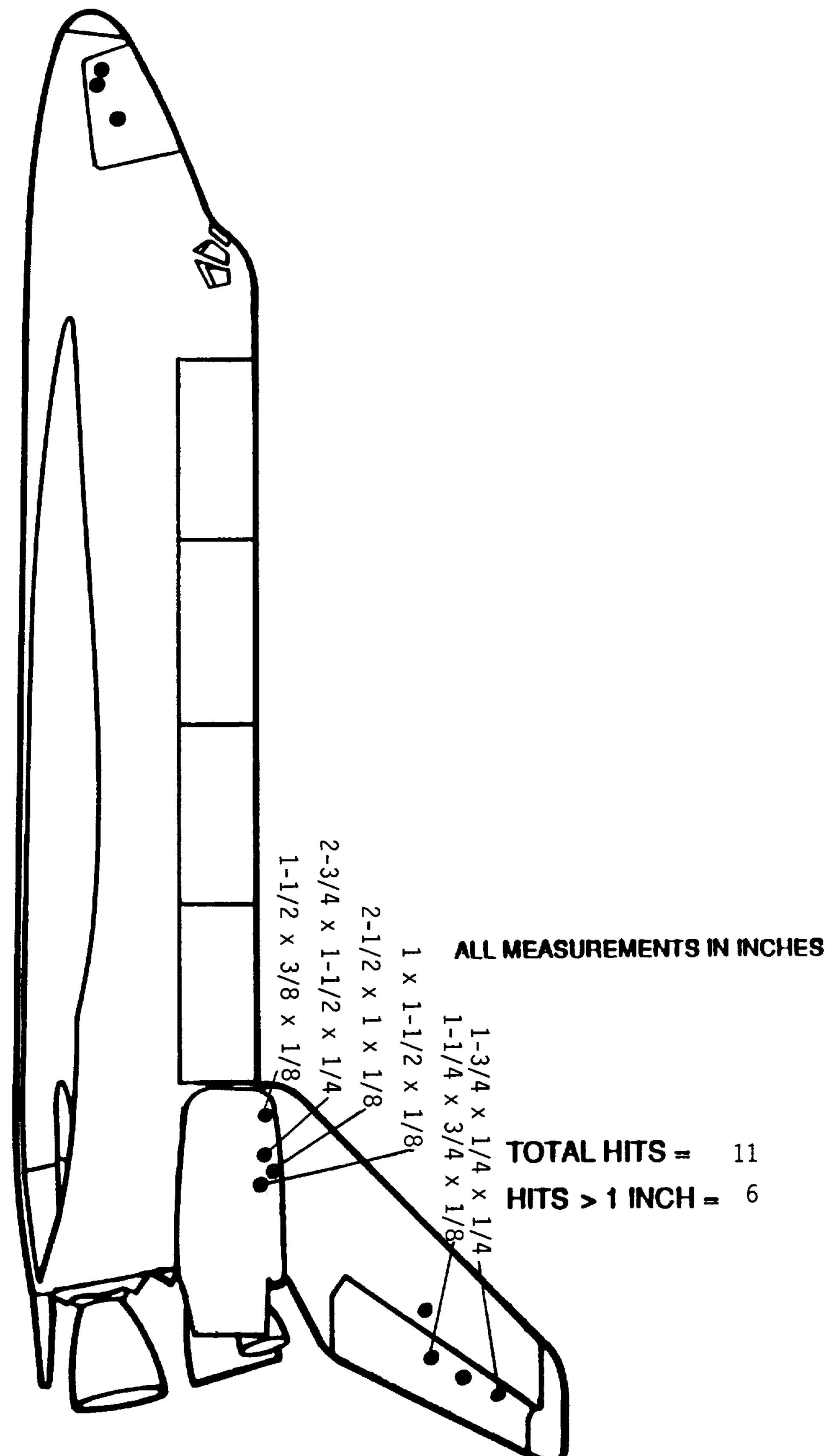
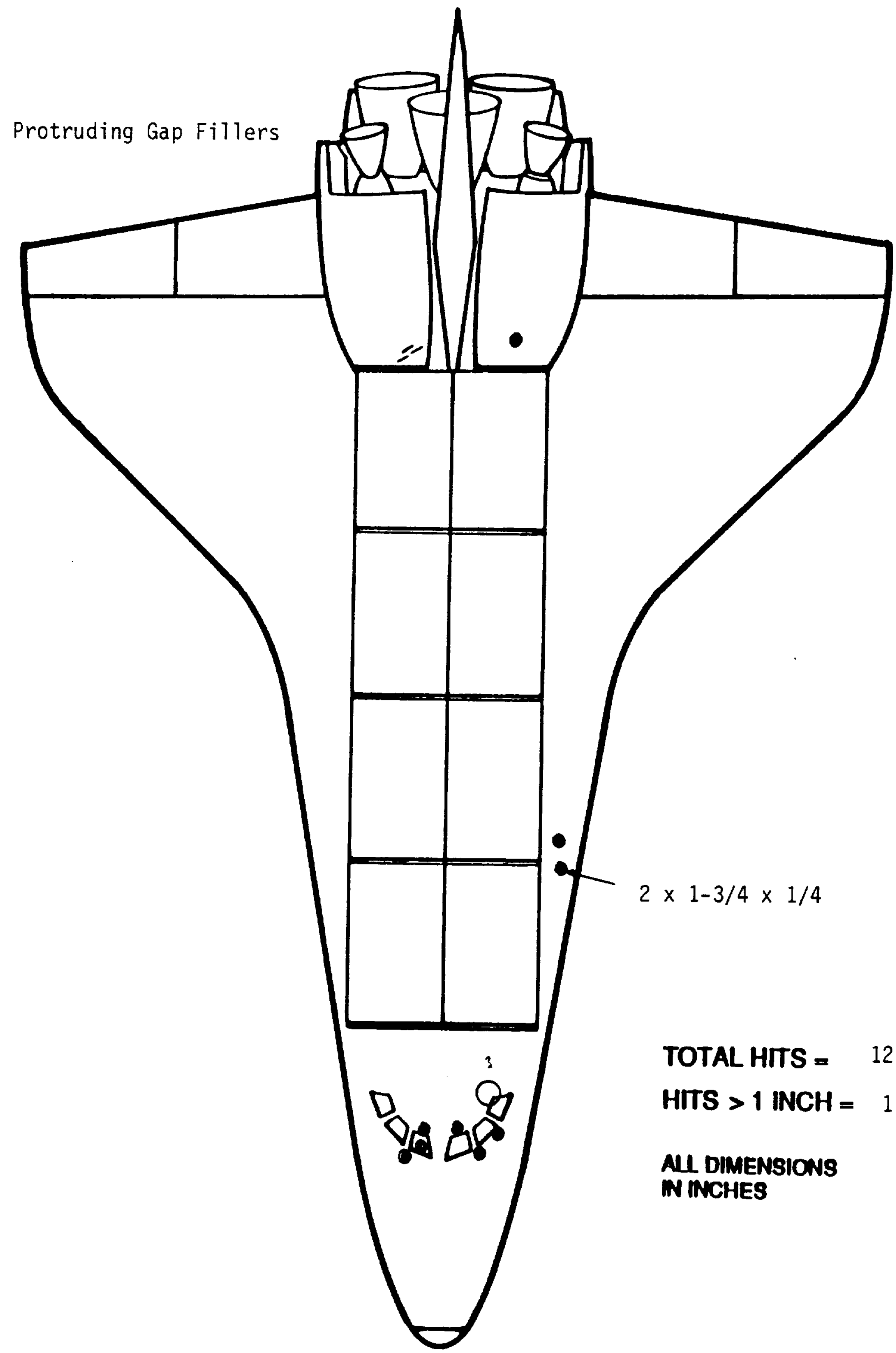


Figure 13. **DEBRIS DAMAGE LOCATIONS**



An expended detonator/electrical connector (2 pieces: P/N SEB 26100001 03-89 19113) from the umbilical separation system fell to the runway when the RH (LO2) ET umbilical door was opened. A PR was initiated by Pyro engineering to document this anomaly. ET/Orbiter (EO) separation ordnance device plungers 2 and 3 were seated and appeared to have functioned properly. No anomalies were externally visible on EO-1.

There was no visible damage to the RCC nosecap or wing leading edge panels. White streaks were present on the RH wing leading edge panels #2, 6, 17, and 18.

All Orbiter windows exhibited lighter than usual hazing. Window #4 exhibited a few light streaks. Wipes were taken from all windows for laboratory analysis. Orbiter window perimeter tile damage was minimal. Detailed examination of the windows revealed on-orbit debris impacts to windows #2, 3, 4, 6, and 8. The depth of the impacts ranged from 0.0029 to 0.0055 inches, which exceeded the acceptance criteria of 0.0006 inches. The depth of the impact site on window #4 was not measured but estimated to be greater than 0.004 inches.

Post flight inspection also revealed 47 dings and micro-meteorite impacts on the radiators. The discrepancies ranged from tape damage to holes through the tape/facesheet. The attitude of the Orbiter during the STS-50 mission is considered to be the major reason for the high number on-orbit debris impacts.

Samples were taken for laboratory analysis from other selected sites as shown in Figure 14.

Damage to the base heat shield tiles was less than average. The SSME #3 DMHS closeout blanket was badly torn and frayed from 8:00 to 10:00 o'clock. Two of the sacrificial patches from this area were missing. The blanket on SSME #2 was in good condition. The sacrificial patch on the SSME #1 blanket from 4:00 to 6:30 o'clock exhibited significant fraying.

Runway 33 was inspected and swept by EG&G SLF personnel on 8 July 1992 and all potentially damaging debris was removed. The condition of the runway was acceptable for landing.

The post landing inspection of Runway 33 was performed immediately after landing. This flight marked the first use of the Orbiter drag chute for a KSC landing and the second time the drag chute was used in the program. The drag chute functioned nominally. However, one tile on the lower (-Z), RH edge of the drag chute door opening was slightly damaged by door ejection. All Orbiter drag chute related hardware was recovered (reference Figure 15) and showed no signs of anomalies. Two FRSI plugs, most likely from the base heat shield area, was the only unexpected flight hardware found on the runway.

Figure 14. **CHEMICAL SAMPLE LOCATIONS**

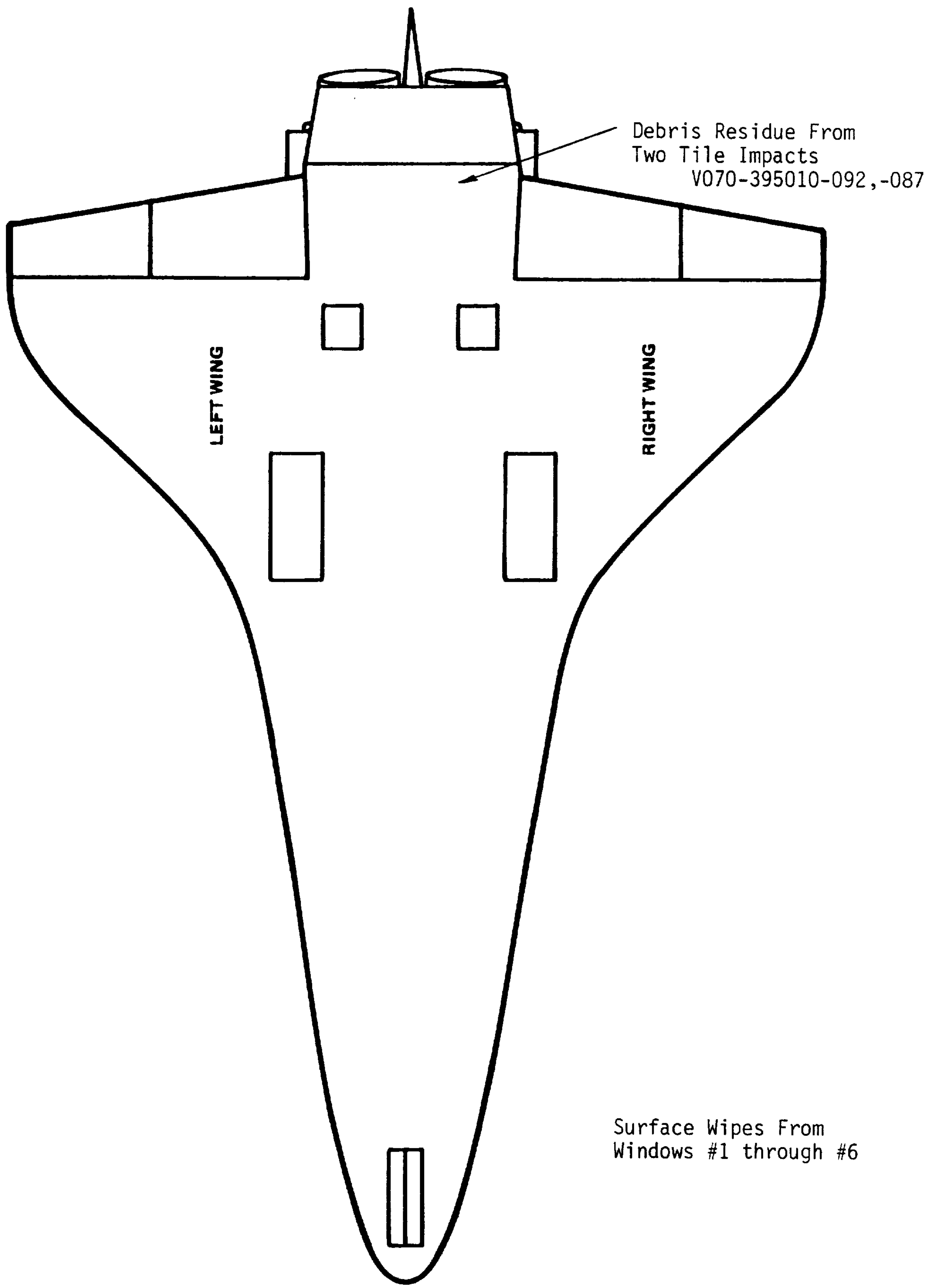
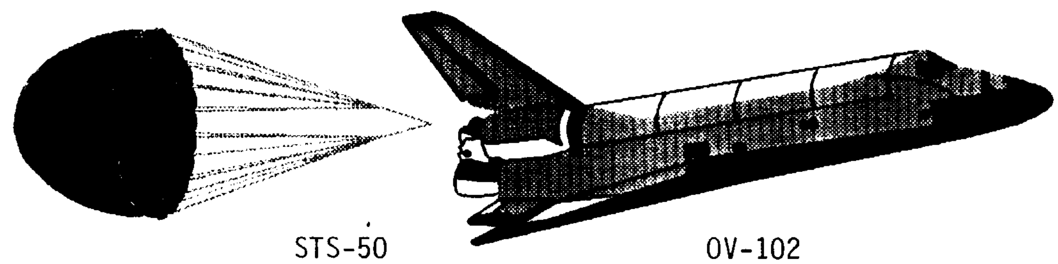
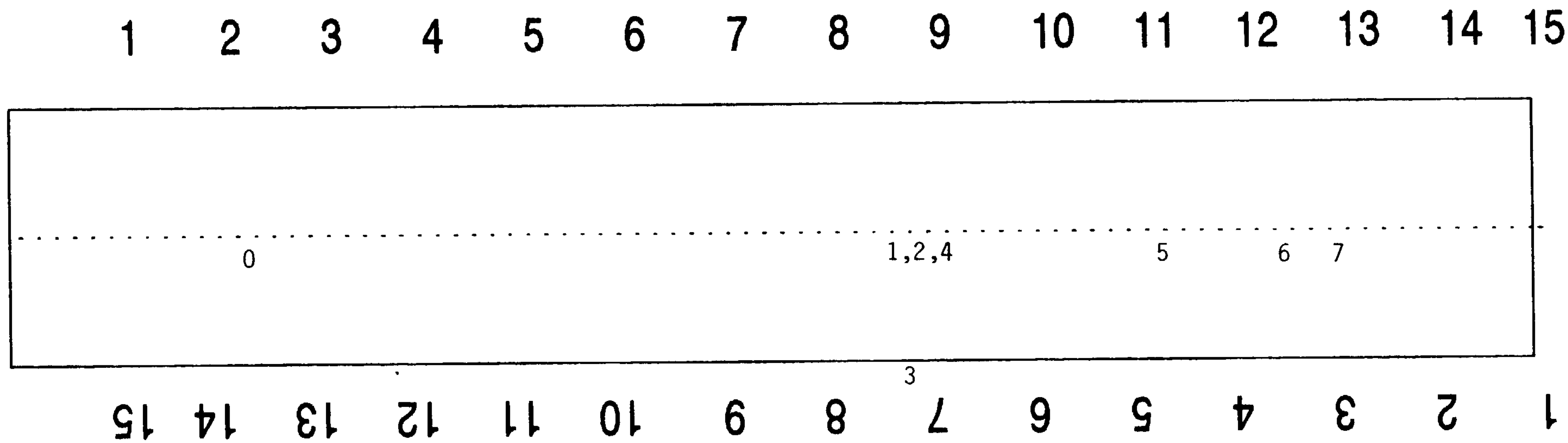


Figure 15.

RECOVERY LOCATIONS OF DRAG CHUTE COMPONENTS





0 - Orbiter touchdown 2300 ft.
1 - Door landed at approx. 8700 ft., bounced three times then slid for 30 ft.
2 - Sabot landed at approx. 8800 ft.
3 - Mortar cover was found at approx. 8800 ft. off edge of runway
4 - Pilot chute was resting at approx. 8950 ft.
5 - Reefing line was found at approx. 11,300 ft.
6 - Main chute was resting at approx. 12,500 ft.
7 - Orbiter wheel stop 13,000 ft.

A portable Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas on the vehicle. Nine minutes after landing the Orbiter nosecap RCC was 202 degrees F. Twenty-two minutes after landing, the RH wing leading edge RCC panel #9 was 118 degrees F and panel #17 was 115 degrees F (reference Figure 16).

In summary, the total number of Orbiter TPS debris hits was higher than average and the number of hits with a major dimension of one inch or greater was much higher than average (by slightly more than two sigma) when compared to previous flights (reference Figures 17-19).

Orbiter Post Launch Anomalies are listed in Section 9.

Figure 16. **STS-50 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

TEMPERATURE MEASUREMENTS

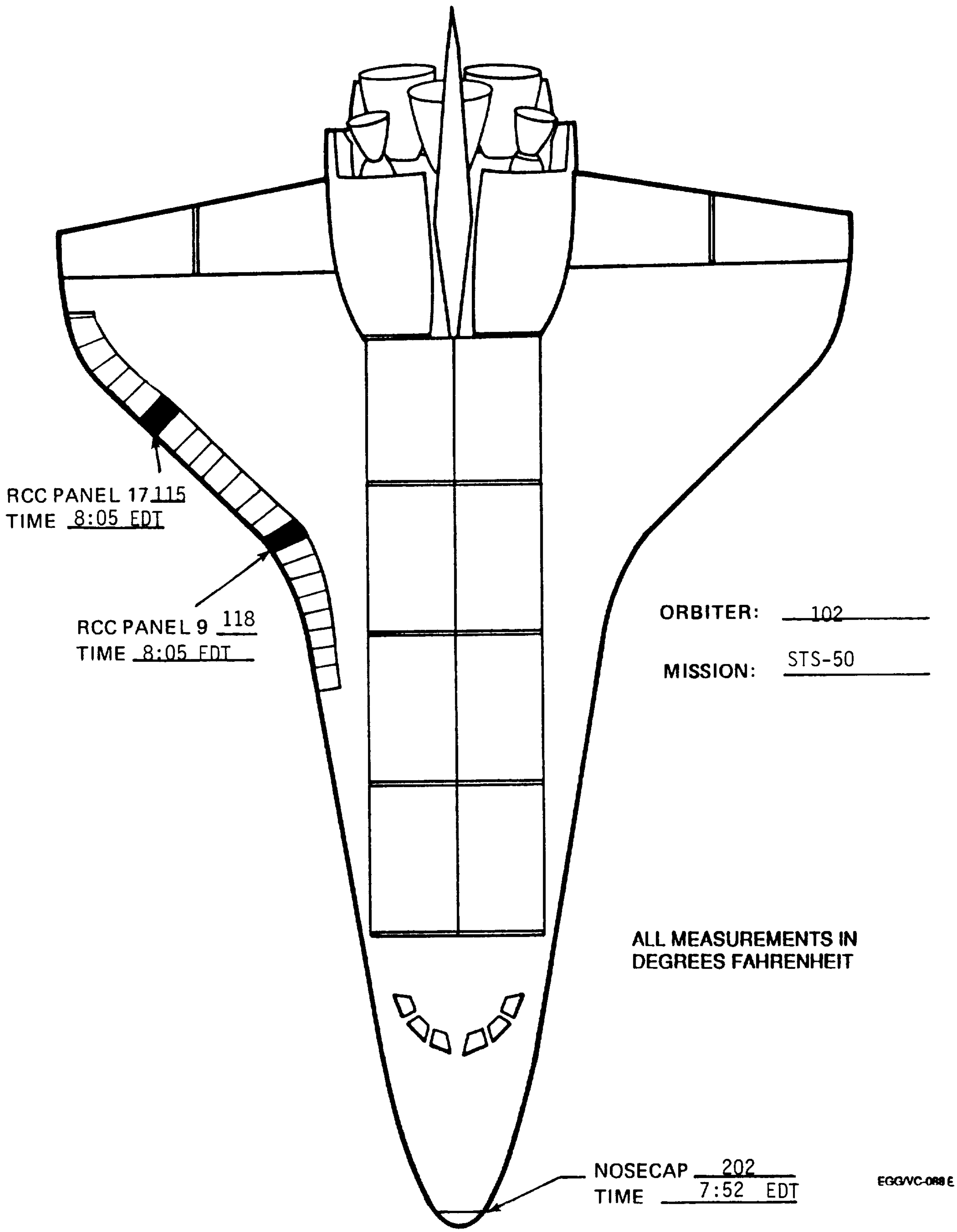


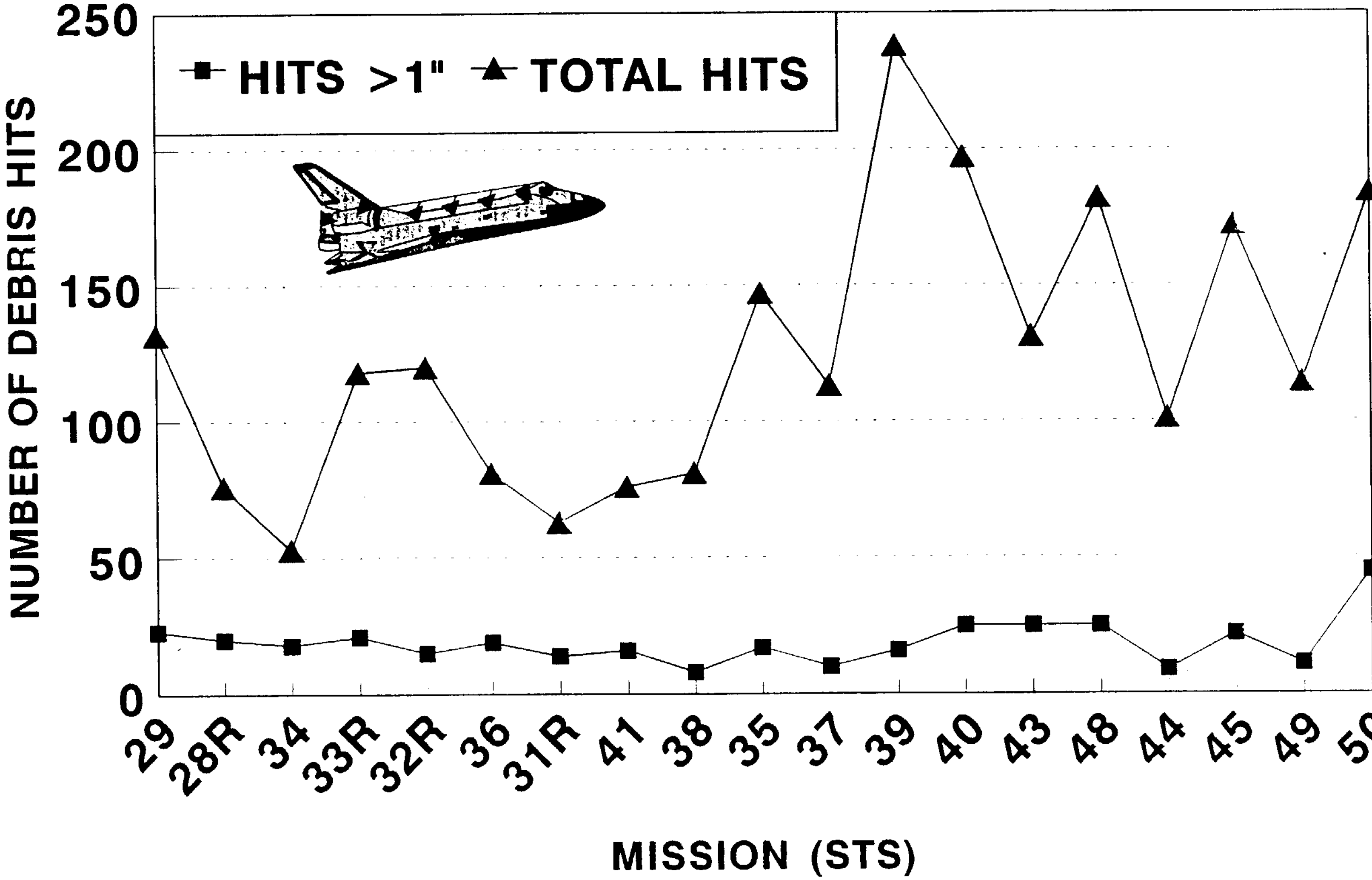
FIGURE 17: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
AVERAGE	15.1	87.2	22.0	120.2
SIGMA	7.3	44.0	10.7	54.0
STS-50	28	141	45	184

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 18.

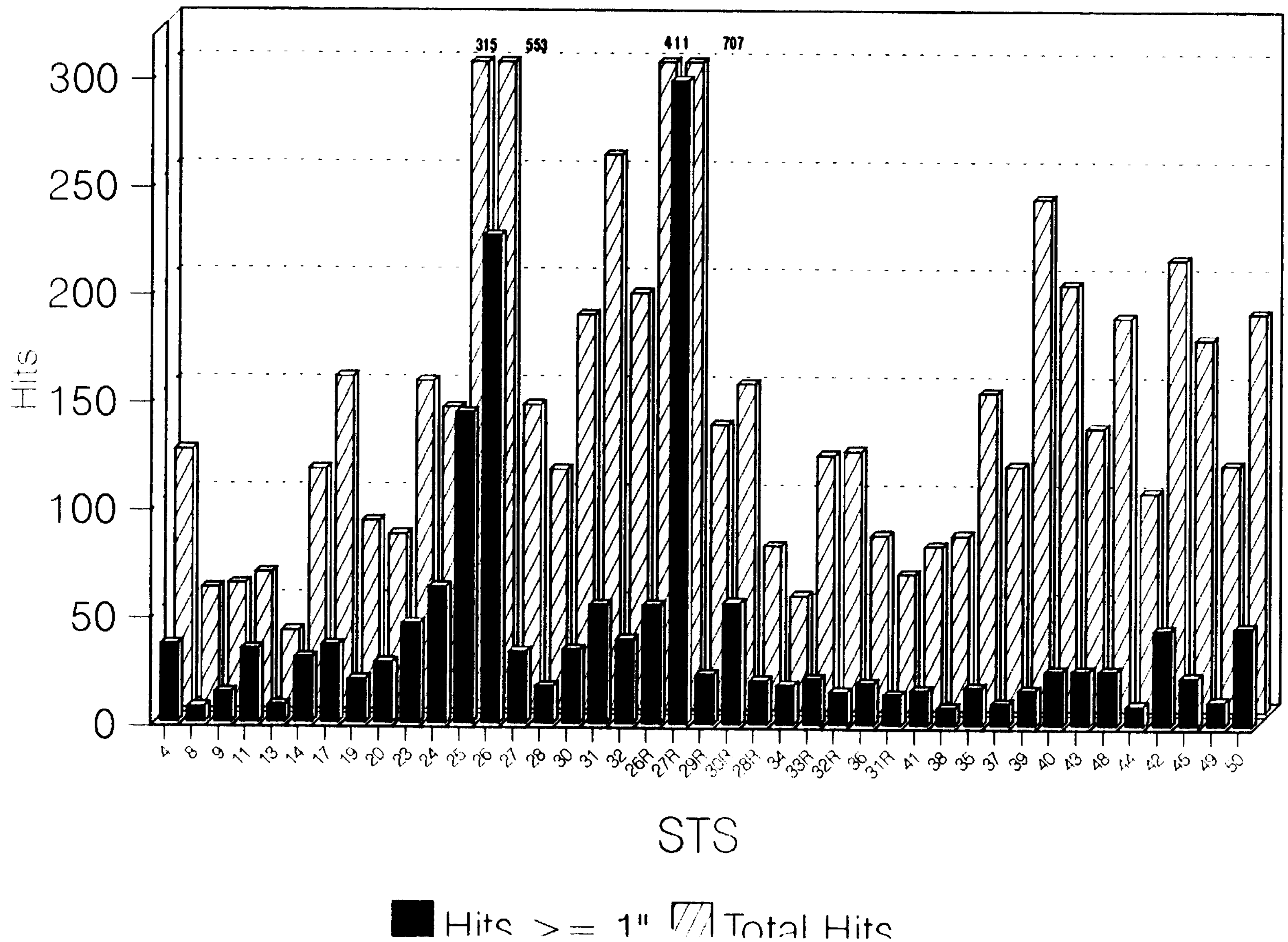
ORBITER TPS DEBRIS DAMAGE
STS-29 THROUGH STS-50

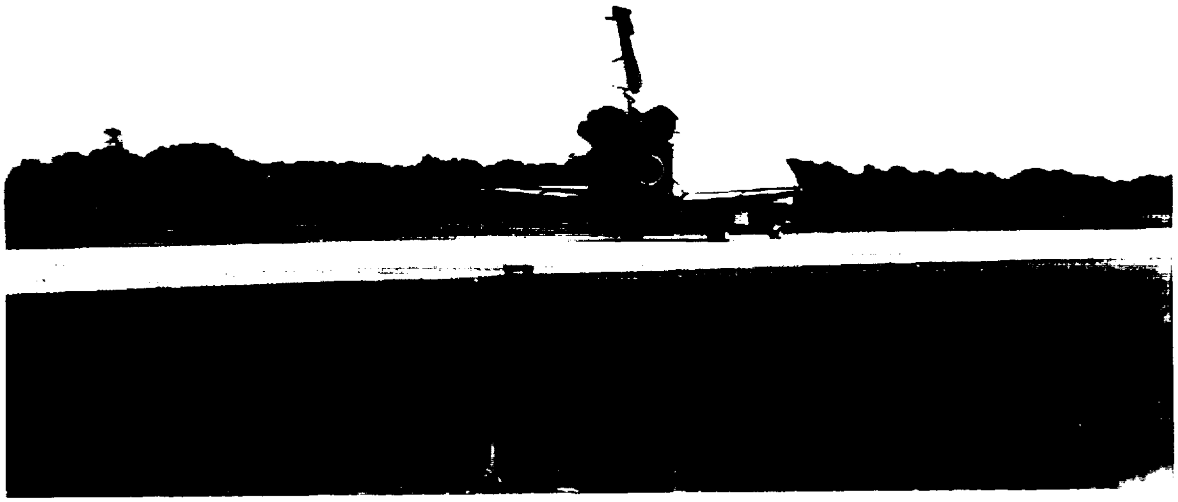


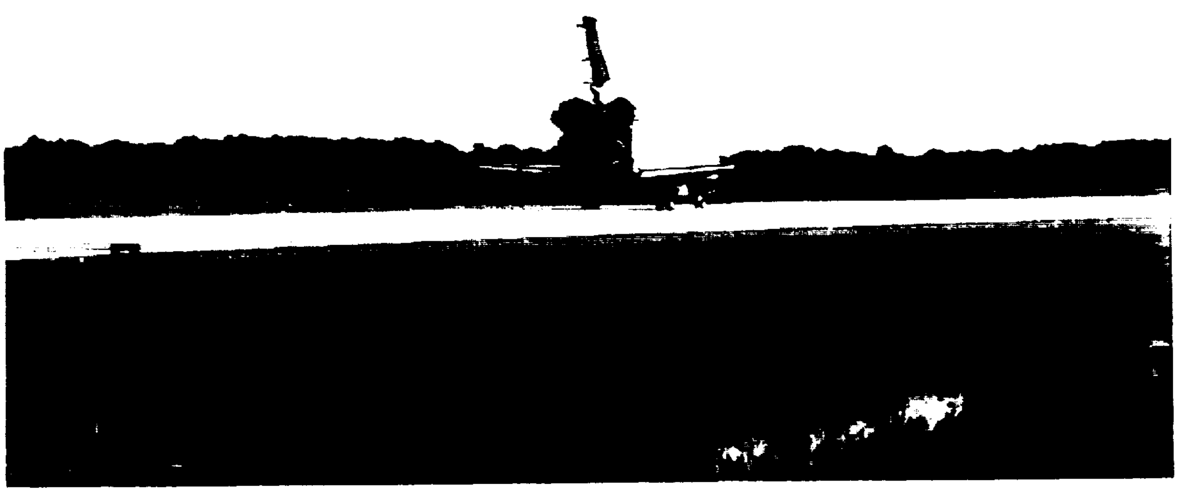
EXCLUDES MISSIONS STS-30R AND 42 WHICH EXPERIENCED SIGNIFICANT DAMAGE FROM KNOWN DEBRIS SOURCES

COMPARISON TABLE

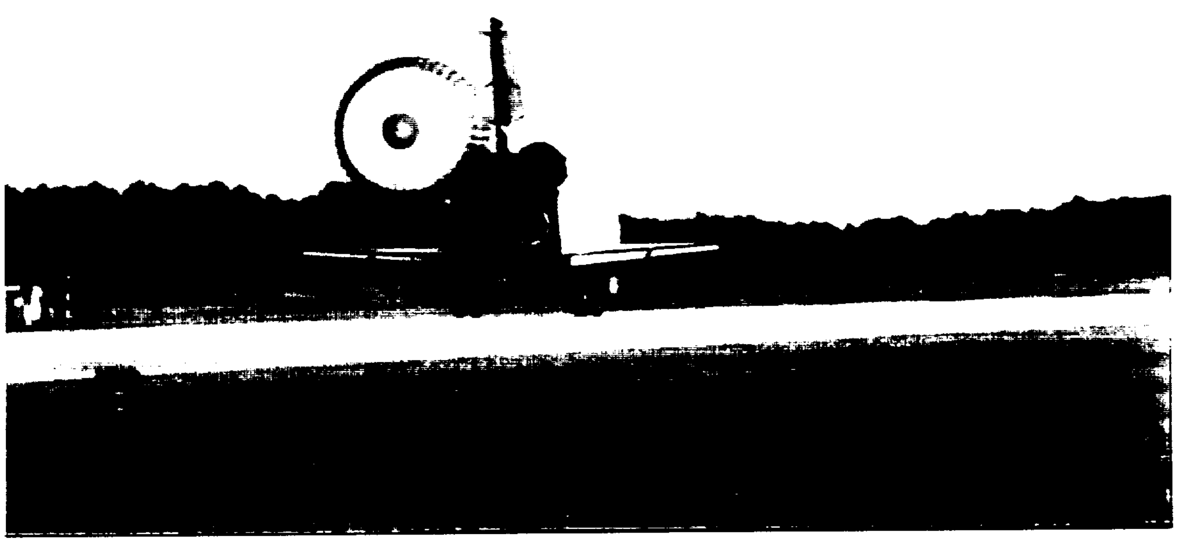
Figure 19.



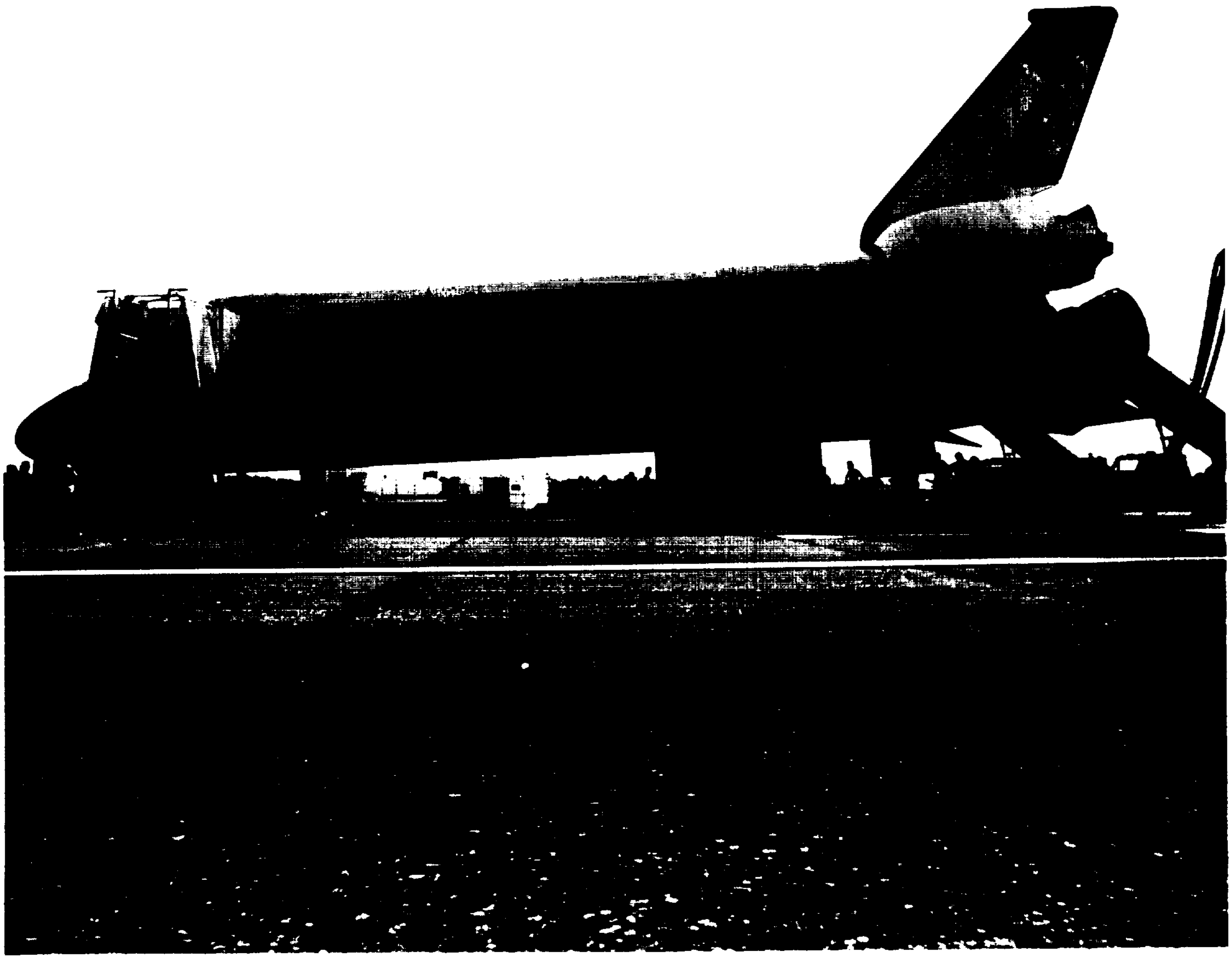




This flight marked the first use of the Orbiter drag chute for a KSC landing and the second time the drag chute was used in the Shuttle program.



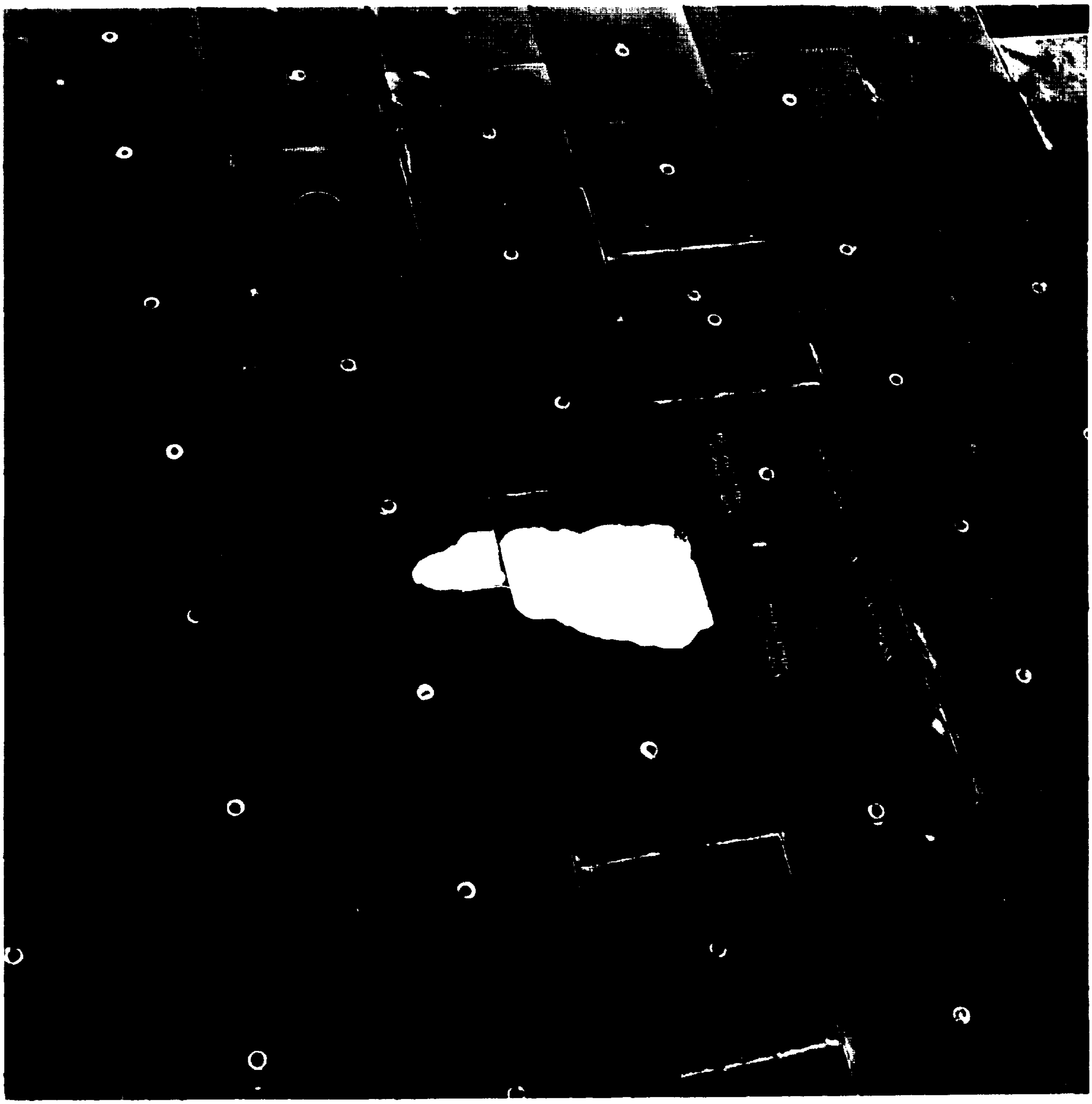
Deployment of the drag chute was nominal. The risers did not contact the SSME #1 nozzle or the rudder/speed brake. All drag chute related hardware was recovered.



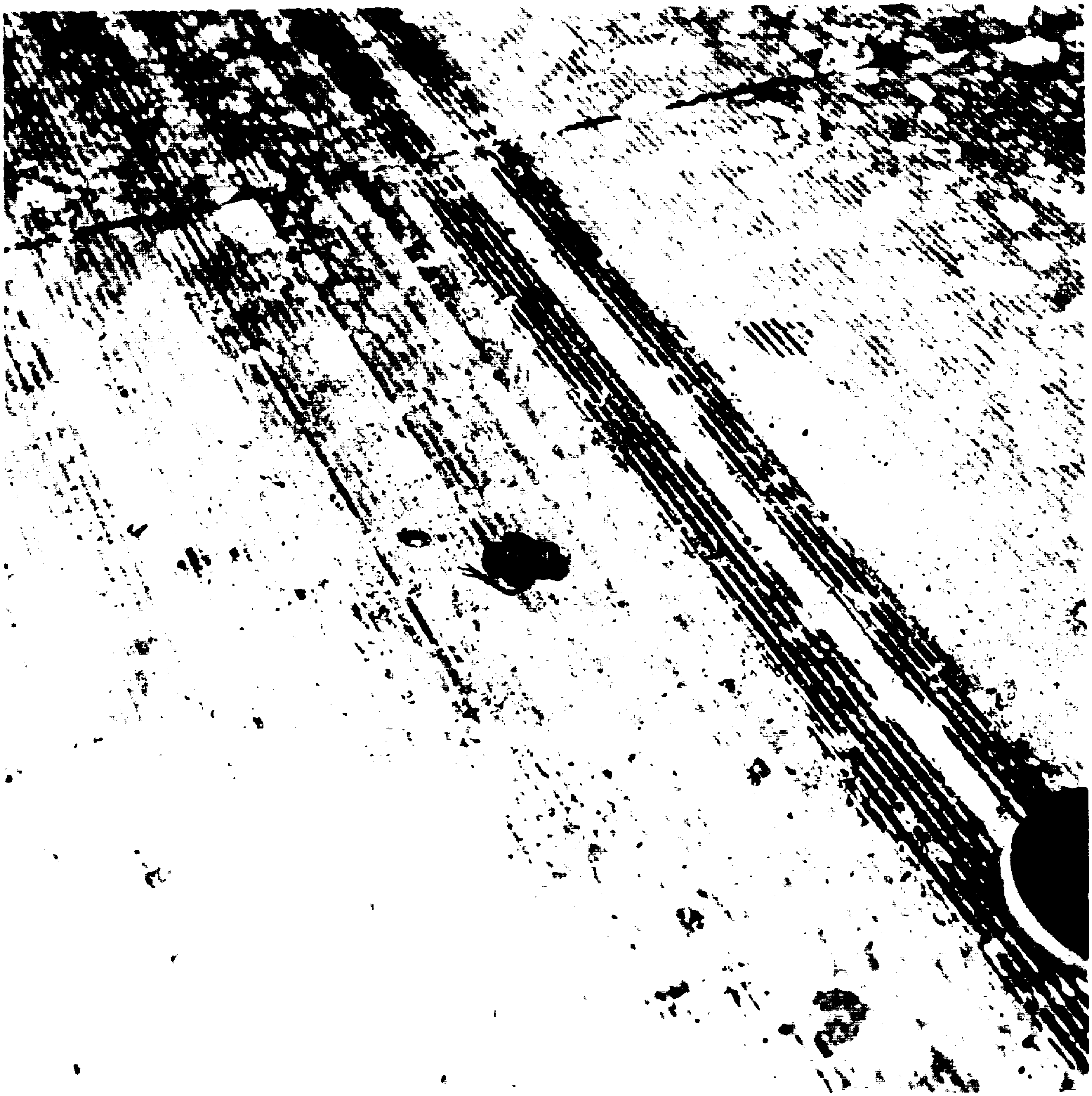
Overall view of Orbiter left side

Overall view of Orbiter right side.

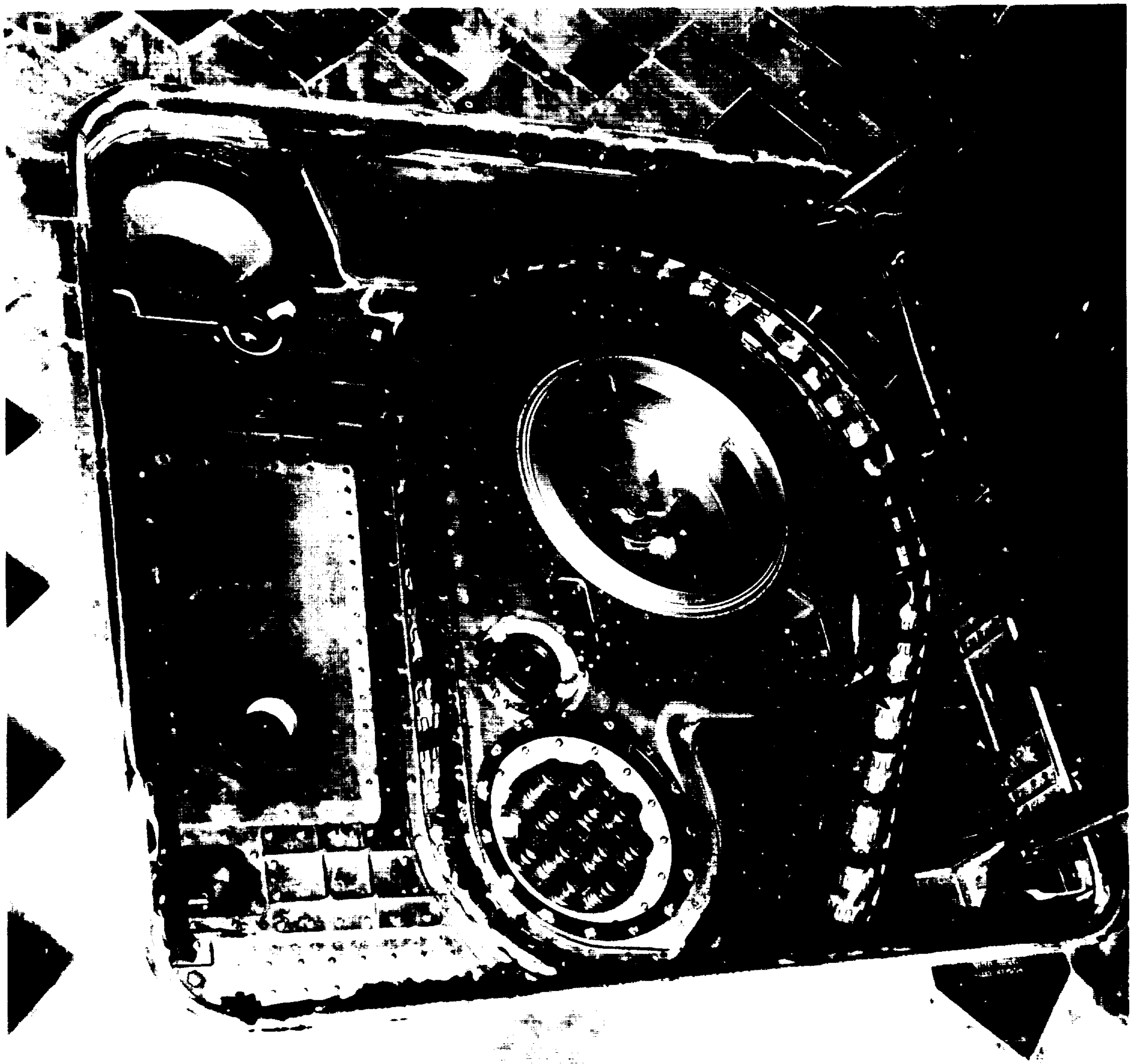
Overall view of Orbiter nose. No anomalies were visible on the forward RCS thrusters



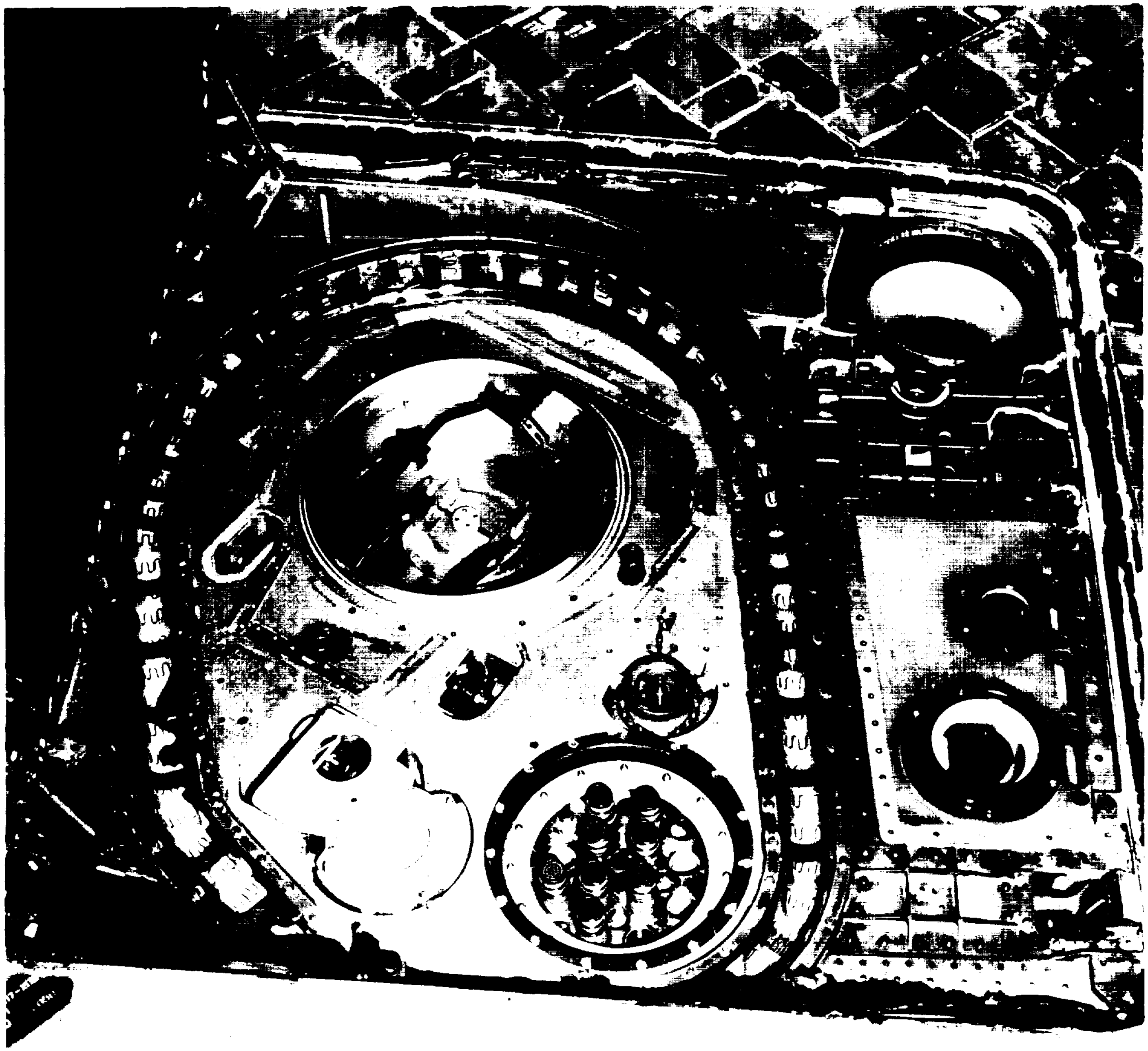
Tile damage site on the left side of the Orbiter approximately 3 feet outboard of the LH2 ET/ORB umbilical measured 9 x 4.5 x 0.5 inches. The size and depth is indicative of an impact by a low density material such as External Tank TPS foam and was most likely caused by the loss of the LH bipod ramp closeout in flight.



An expended detonator/electrical connector from the umbilical separation system fell to the runway when the RH (LO2) ET/ORB umbilical door was opened.

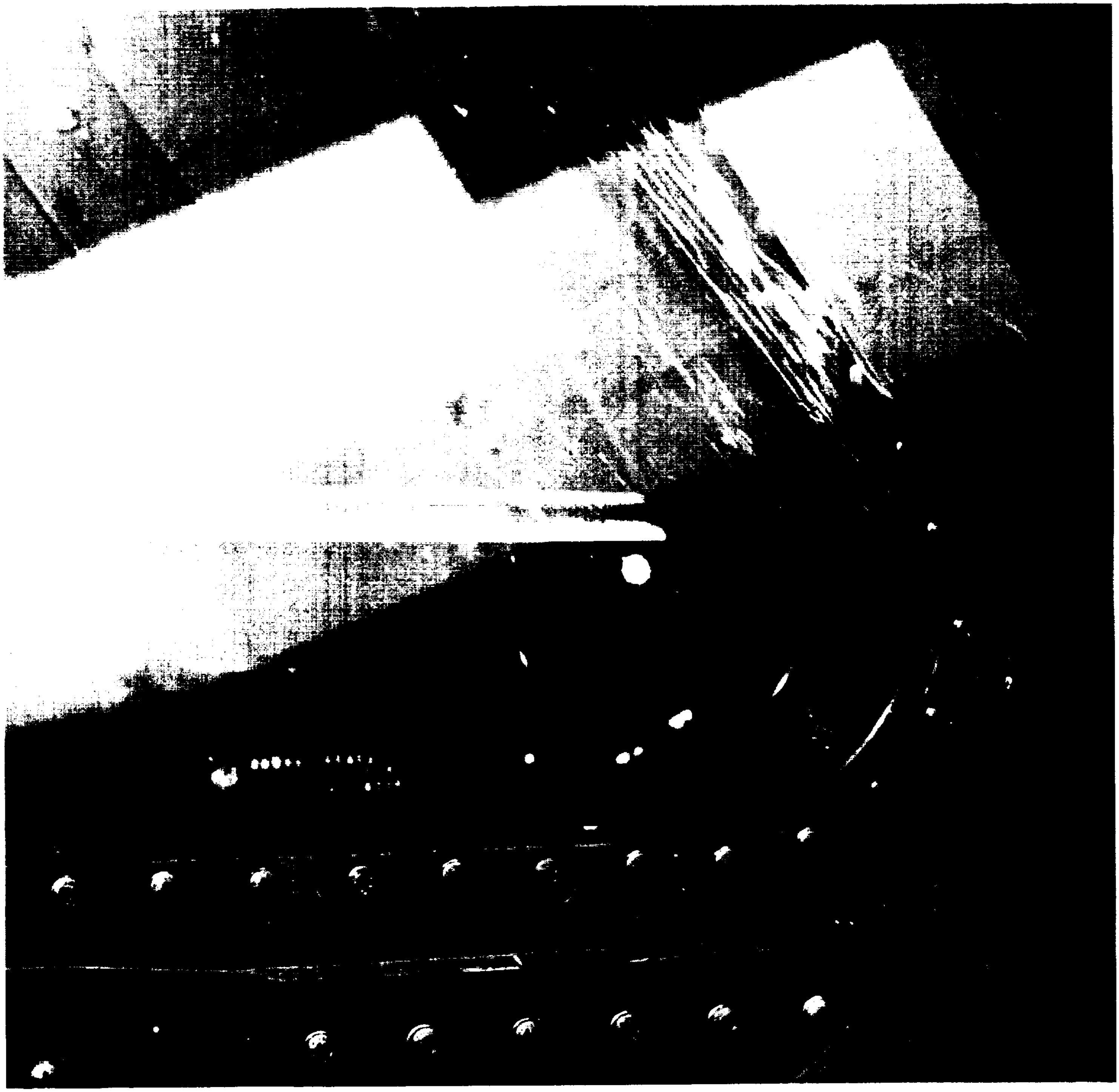


Overall view of the LO2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly.



Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly.

All Orbiter windows exhibited lighter than usual hazing with a few light streaks visible on window #4



The depth of an impact site on window #4 was estimated to be 0.004 inches, which exceeds the acceptance criteria of 0.0006 inches

Damage to the base heat shield tiles was less than average. The SSME #3 DMHS closeout blanket was badly torn and frayed from 8:00 to 10:00 o'clock. Two of the sacrificial patches from this area were missing.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of 11 samples were obtained from Orbiter OV-102 during the STS-50 post landing debris assessment at Kennedy Space Center (Figure 14). The eleven submitted samples consisted of 8 window wipes, 2 residual samples from damage sites on the lower surface tiles, and 1 residual sample from an Orbiter vertical stabilizer tile damage site. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves the placing and correlating of particles with respect to composition, thermal (mission) effects, and availability. Debris sample results and analyses are listed by Orbiter location in the following summaries.

Orbiter Windows

Results of the window sample analysis revealed the presence of the following materials:

1. Metallics
2. RTV, silica tile, glass fibers, insulation
3. Cerium-rich materials
4. Paints, dust, rust, and salt
5. Organics
6. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (brass, aluminum, zinc and carbon steel alloys) are common to SRB/BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. RTV, silica tile, glass fibers, and insulation originate from Orbiter thermal protection system (TPS).

3. Cerium-rich materials originate from Orbiter window polishing compounds.

4. Paint is of flight hardware/facility/GSE origin; dust and salt are naturally-occurring landing site products; rust is an SRB BSM exhaust residue.

5. Organics were found to be cellulosic fibers (sample cloth); polymeric (urethane,nylon), phenolic/acrylic and butyl adhesive, which is typical of protective cover type materials.

6. Earth compounds (calcite, salt and alpha-quartz) originate from the landing site.

Orbiter Tile Damage Site

Results of the Orbiter tile damage site samples indicated the presence of the following materials:

1. Silica-rich dense tile (coating)
2. Silica-rich fibrous tile

Debris analysis provides the following correlations:

1. Silica-rich dense tile (coating) originates from the Orbiter thermal protection system (TPS).

2. Silica-rich fibrous tile originates from the Orbiter thermal protection system (TPS).

Orbiter Vertical Stabilizer

Results from the Orbiter vertical stabilizer tile damage site revealed the presence of the following materials:

1. Silica-Aluminum-Calcium glass fiber
2. Silica-rich coating

Debris analysis provides the following correlations:

1. Silica-Aluminum-Calcium glass fiber is identifiable as an E-glass, such as MBO-135-009, but is typically used as a structural coating under TPS and is not usually found on Orbiter exterior surfaces. However this type material can be found on other spacecraft. In this specific case, no transport mechanism has been identified.

2. Silica-rich coating originates from the Orbiter TPS

Conclusions

The STS-50 mission sustained Orbiter tile damage to a greater than average degree. The chemical analysis results from post flight samples did not provide data that points to a single source of damaging debris. This report includes STS chemical sampling results from previous missions in tabular format (reference Figure 20) though the information contained in the table did not provide trend data to account for the increase in debris damage sites for this mission.

Orbiter window samples revealed Orbiter TPS, window polishing compound, BSM exhaust residue, landing site products, organics, and paint. The Orbiter tile damage site sample results provided evidence of TPS materials. A structural coating-type material was found at the vertical stabilizer damage site and is still under investigation.

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
49	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Calcium, Salt (Landing Site) Organics Paint	RTV, Tile (ORB TPS) Rust - BSM Residue (SRB) Muscovite, Salt (Landing Site) Organics Paint	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Rust - BSM Residue (SRB) Calcium Mat'l,Salt (Landing Site Soil) Organics Paint		
45	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint		Iron - Rich Mat'l Paint		
42	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint		Metallics - BSM Residue (SRB) Tile, Tile Coating (ORB) Salt (Landing Site) Paint	Organics	RH Fuselage - Tile Coating (ORB)
44	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Organics Silica-Magnesium Mat'l	
48	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Metallics Silica - Rich Mat'l (Landing Site) Orb Umbilical C/O Mat'l (ORB) Paints	
43	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint		RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Salt (Landing Site) Organics Paint		Runway - FRSI Coating (ORB)

Figure 20. Micro-chemical Analysis Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
40	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint	RTV,Tile (ORB TPS)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Organics (ORB Umb C/O) Paint	
39		Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint Hypalon Paint (SRB)	Tile (ORB TPS) Insulation Glass (ORB TPS)		
37	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics Paint	RTV, Tile ((ORB TPS) Insulation Glass (ORB TPS) Metallics - BSM Residue (SRB) Calcite, Salt (Landing Site) Organics		
35	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Organics	RTV, Tile (ORB TPS) Metallic - Rust, Aluminum Welding Slag (Facility)		
38		RTV, Tile (ORB TPS) Hypalon Paint (SRB) Ensolite Foam (RCC Prot. Cover)	Tile (ORB TPS)		
41	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Tile (ORB TPS) Salt (Landing Site)	Tile (ORB TPS)	Calcite (Landing Site) Fluorocarbon (Viton-ORB Umb) Foam (ORB C/O)	Fwd FRSI - Silicon Mat'l (ORB TPS)
31R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Foam Insulation (ET/SRB) Paint	RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Mica (Landing Site) Paint		
36	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Mica, Salt (Landing Site) Paint	Rust - BSM Residue (SRB) Tile (ORB TPS) Paint Organics	RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Mica (Landing Site) Organics Microballoon (ET/SRB)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Microballoon (ET/SRB) Calcite (Landing Site) Foam, Organics (ORB Umb C/O)	

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
32R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Mica, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) Tile (ORB TPS) Carbon Fibers Titanium	Metallics - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Quartz, Calcite (Landing Site) Organics	
33R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Micaceous Mat'l, Salt (Landing Site) Window Polish Residue (ORB) Paint	Metallics - BSM Residue (SRB) Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Spar, Salt (Landing Site) Organics	RTV, Tile (ORB TPS)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Paint Organics	Crew Hatch Window - Rust - BSM Residue (SRB) - Alpha Quartz (TPS/Landing Site) - Paint - Organics
34	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Alpha-Quartz, Silicates, Salt (L/S) Window Polish Residue (ORB)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Paint	RTV, Tile (ORB TPS) Stainless Steel Washer	RTV (ORB) Foam (ORB) Viton Rubber (ORB) Metallics - BSM Residue (SRB) Phenolic Microballoon (ET/SRB) Silicates, Calcium (Landing Site) Paint	
28R	Silicone (ORB FRCS Cover Adhesive)	Silicates (Landing Site) Paint Charred Silicone Brass Chip	RTV, Tile (ORB TPS) Clay, Sand, Quartz (Landing Site) Metallics - BSM Residue (SRB)	Sand, Silicates (Landing Site) Foam (ORB) RTV (ORB TPS) Koropon, Kapton (ORB) Metallics - BSM Residue (SRB)	OMS Pod - PVC Laminate (ORB TPS 'Shim')
30R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Clay, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Gap Filler (ORB TPS) Clay, Feldspar (Landing Site)		Upper Tile - Tile,Gap Filler (ORB TPS)
29R	RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Ablator, Hypalon Paint (SRB)		Tile (ORB TPS) Insulation Glass (ORB TPS) Paint Muscovite - Metallics (Landing Site)	Tile (ORB TPS) Umbilical Foam (ORB) Paint Ablator, Hypalon Paint (SRB) Metallics - BSM Residue (SRB)	Upper Tile - Tile (ORB TPS)
27R	RTV, Tile (ORB TPS)	Hypalon Paint (SRB)	RTV, Tile (ORB TPS) Ablator, Hypalon Paint (SRB)		OMS Pod - Iron Fiber - PDL Foam, FRL Paint (ET) - Ablator, Hypalon Paint (SRB)
26R			RTV, Tile (ORB TPS) Paint Rust		

Sample locations vary per mission and not all locations are sampled for every mission.
( ) - identifies the most probable source for the materail.
Metallics - includes mostly Aluminum and Carbon Steel alloys

Figure 20. Micro-chemical Analysis Results

9.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 12 Post Launch Anomalies, including three IFA candidates, were observed on the STS-50 mission.

9.1 LAUNCH PAD/FACILITY

1. A loose electrical conduit cap on the east side of the SSME flame exhaust hole was removed during the Ice Team Inspection at T-3 hours.

9.2 EXTERNAL TANK

1. Approximately 60 percent of the LH bipod ramp closeout was missing to a depth that exposed part of the spindle housing along with some of the intertank acreage foam at the leading edge of the ramp (26" x 10" total damage site). Debris damage to Orbiter TPS was greater than average including a 9"x4.5"x0.5" damage site on the lower surface approximately 3 feet outboard of the LH2 umbilical. Loss of the bipod ramp closeout could be the result of TPS material failure on the ET intertank acreage due to inadequate venting. This event appeared similar to the occurrence on STS-7. (IFA STS-50-I-01)

2. The RH jack pad closeout and some adjacent foam was missing creating a 6-inch diameter divot. (IFA candidate)

3. Numerous areas of TPS erosion and small divots occurred on the thrust strut flange closeouts, the LO2 feedline flange closeouts, six of the pressurization line ramps, and two of the cable tray ice/frost ramps. A 7-inch diameter divot occurred on the inboard side of the LO2 feedline support bracket at XT-1377.

4. Small divots and TPS erosion occurred on the LO2 ET/ORB umbilical cable tray (horizontal section). Six divots, including one that spanned the entire width of the cable tray, were present on the +Z side of the vertical section.

9.3 SOLID ROCKET BOOSTERS

1. The RH frustum was missing no TPS but had 26 MSA-2 debonds over fasteners. The LH frustum had 15 MSA-2 debonds over fasteners and was missing MSA-2 (2-inch diameter) from one location near the -Z axis.

2. A stud hang-up occurred on HDP #4. A 6"x3" piece of the EPON shim material had been pulled off by the stud at liftoff.

3. A 2"x1" piece of EPON shim material was lost from the HDP #3 aft skirt foot prior to water impact.

4. Three divots to substrate (2.8"x2.0" at 180 degrees; 2.6"x2.0" at 186 degrees; 3.0"x2.0" at 192 degrees) were present in the GEI cork closeout at XB-1099 on the forward center segment. One of the divots was sooted on the forward edge of the material. The surrounding cork material was unbonded. (IFA STS-50-M-01)

9.4 ORBITER

1. An orange GSE tile shim originated near the R1A thruster and fell aft during SSME ignition.

2. The Orbiter TPS sustained a total of 184 hits, of which 45 had a major dimension of one inch or larger. The total number of Orbiter TPS debris hits was higher than average and the number of hits with a major dimension of one inch or greater was much higher than average when compared to previous flights.

3. An expended detonator/electrical connector (2 pieces: P/N SEB 26100001 03-89 19113) from the umbilical separation system fell to the runway when the RH (LO2) ET umbilical door was opened.

Appendix A. JSC Photographic Analysis Summary

August 17, 1992

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-50 Final Report, and was completed August 10, 1992. Publication numbers are LESC-30375 and JSC-25951. The actual document can be obtained through the LESC library/333-6594 or Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

2.0 Summary of Significant Events Analysis

2.1 Launch Events

The launch of STS-50 occurred normally. No events were observed which were not within the experience base of the JSC screening personnel. Normal events observed included: normal pad debris; SRB flame duct debris; RCS paper debris; white debris (probably ice) from the ET/Orbiter, TSM umbilical areas and the GUCP disconnect during liftoff; vapor from the GUCP after liftoff; twang; slight vibration from the elevons at liftoff; MLP debris in the SLV exhaust plume after liftoff; ET aft dome outgassing and charring after liftoff; vapor off SRB stiffener rings after liftoff; condensation trails from the SLV after the roll maneuver; multiple white flashes in the SSME plume at approximately 14 to 16 seconds MET; indication of wind shear in the SRB plume; atmospheric bow waves; dark puffs in the SRB plume and SRB exhaust plume brightening at tail off. Other than the RSRB bolt hang up on HDP #M-4 the following items are not considered anomalous but merit mentioning. A detailed analysis for some of these events is located in Appendix D.

2.0 Summary of Significant Events Analysis

2.2 RSRB Bolt Hang Up at Holddown Post #M-4

(Camera E-007)

Figure 2.2 (A) RSRB Holddown Bolt Hang Up - Fully Extended

A bolt hang up on the RSRB holddown post #M-4 was noted. The bolt hung up in the SRB debris containment system (DCS) area. Full extension of the bolt occurred at 0.554 seconds MET. At this time, the top of the bolt was 10 inches above the shoe. After the bolt release, the bolt had a sudden small deflection to the left of the camera field of view. Three pieces of epon shim material were noted falling from the SRB foot during the time of bolt hang up

A review of previous occurrences of bolt hang ups since reflight was conducted. Bolt hang ups have occurred on five previous missions since reflight. Four of the five bolt hang ups were on the RSRB. The other missions where bolt hang ups have occurred were STS-34 (RSRB holddown post #M-2), STS-33 (RSRB holddown post #M-3), STS-39 (RSRB holddown post #M-1), STS-43 (LSRB holddown post #M-7), and STS-45 (RSRB holddown post #M-4). No further photographic analysis is expected.

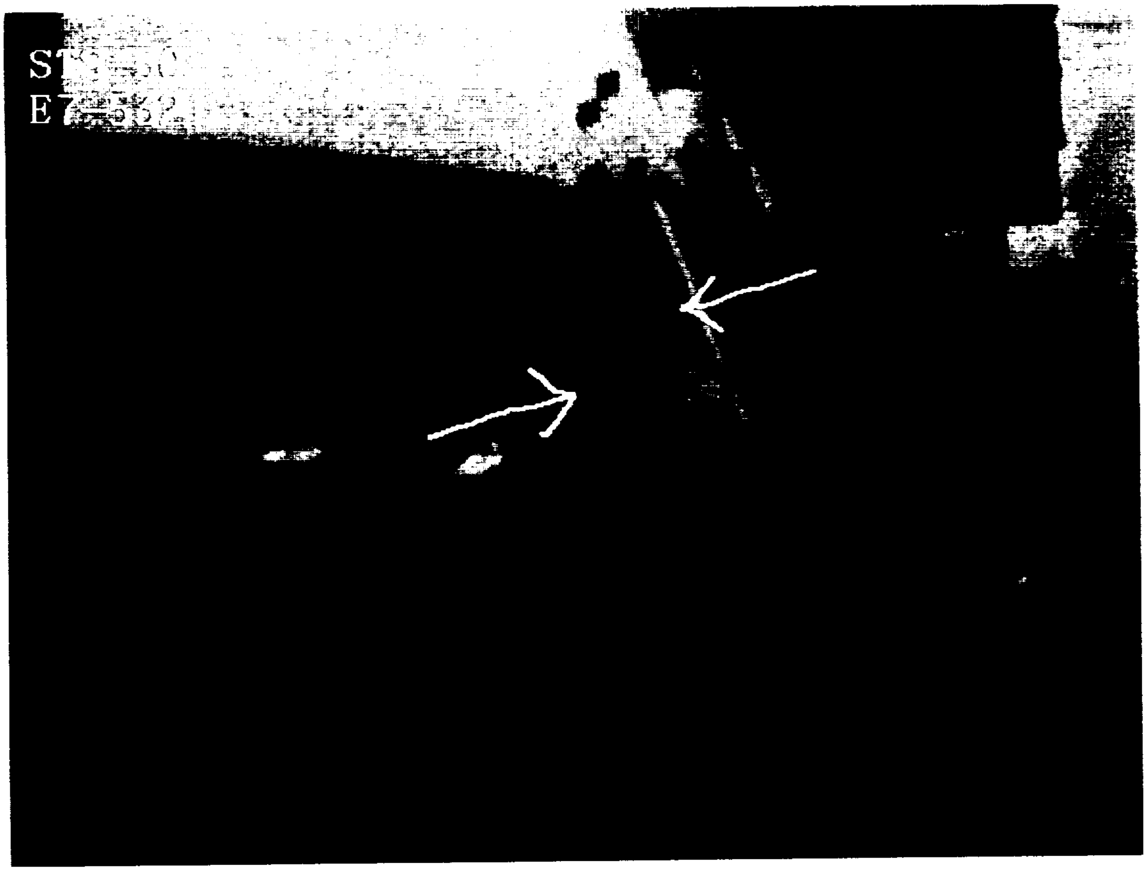


Figure 2.2 (B) RSRB Holddown Bolt Hang Up - Retracting

2.3 Debris

Other than the small orange piece of debris seen on camera E-012, none of the debris described below was visually confirmed to strike the launch vehicle.

2.3.1 Debris Near the Time of SSME Ignition
(Camera OTV-009)

A small light-colored piece of debris (possibly ice) originated from the LH2 ET/Orbiter umbilical disconnect area, traveled toward the 4" recirculation line and then fell aft prior to liftoff. This debris may have hit the 4" line but no damage to the umbilical was visible.

2.0 Summary of Significant Events Analysis

The usual amount of ice debris from the LO2 and LH2 TSM T-0 umbilicals and the ET/Orbiter umbilicals were noted on many of the MLP camera films prior to and during liftoff.

2.3.2 Debris Near the Time of SRB Ignition

2.3.2.1 DCS Debris at Liftoff

(Camera E-012)

A single small dark piece of debris appeared to originate from the LSRB HDP #M-5 debris containment system (DCS) area at PIC firing and fell into the LSRB flame duct.

2.3.2.2 Debris Falling along the Left Inboard Elevon

(Camera E-018)

Two flat white/red pieces of debris fell aft along the left inboard elevon prior to liftoff. The origin of the debris could not be determined. The debris did not appear to strike the vehicle.

2.3.2.3 Debris Striking the LSRB Aft Skirt

(Camera E-012)

A small orange piece of debris (origin unknown) struck the LSRB aft skirt at SSME startup. No damage was noted.

2.3.2.4 RCS Butcher Paper Near the Vertical Stabilizer

(Camera OTV-070)

A single small light-colored piece of debris originated from behind the vertical stabilizer and moved into the SSME exhaust plume area at 0.656 seconds MET. The debris did not appear to strike the vehicle. This debris was determined to be RCS butcher paper on subsequent camera views.

2.3.2.5 Flexible Debris from the RSRB Flame Duct *(Task #7)* *(Camera E-001, E-004, E-015)*

A single dark flexible piece of debris originated from the RSRB flame duct and traveled north away from the vehicle at liftoff.

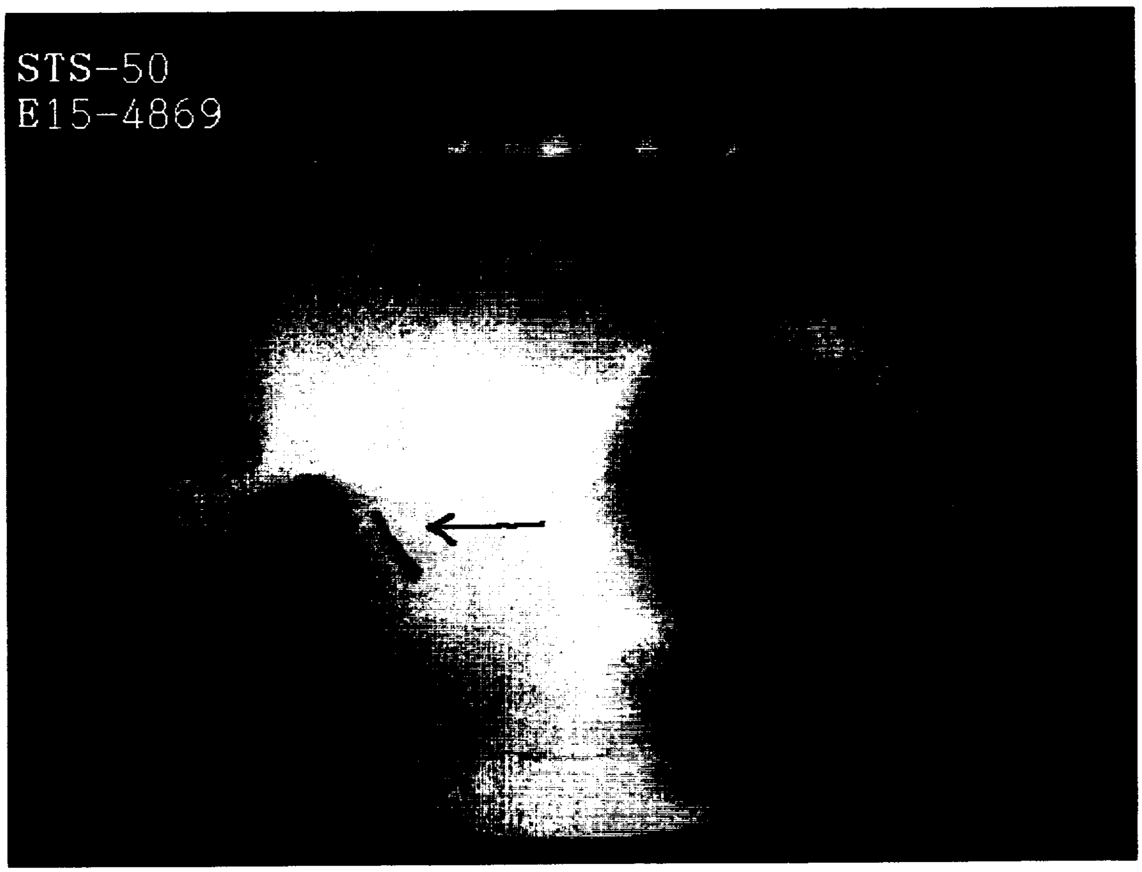


Figure 2.3.2.5 RSRB Duct Debris

A flexible piece of dark debris was noted coming from the RSRB flame duct area during screening of the mission photography. The trajectory of this piece of debris was digitized on a Film Motion Analyzer from Cameras E-001 and E-015 film. The debris emerged from the flame duct area after liftoff and fell back into the flame duct area as the vehicle traveled away from the MLP. Velocity was calculated using a two camera solution. The velocity of this flexible debris was 17.9 feet per second over the entire interval. The observed debris did not appear to strike the vehicle. A plot of position versus time is in Appendix D Task #7.

2.3.3 Debris After Liftoff

2.3.3.1 Debris Observed After Roll Maneuver
(Camera E-212, E-213)

A single light colored piece of debris, probably baggie material, originated from behind the left inboard elevon and fell aft following roll maneuver.

A single piece of white debris, probably RCS paper, fell aft along the inboard area of the right wing after the roll maneuver.

2.3.3.2 Numerous Pieces of Debris of Unknown Origin
(Cameras E-213, E-222)

Multiple pieces of white debris were seen falling aft of the SLV after the roll maneuver at 28.267 seconds MET.

2.4 MLP Events

2.4.1 Base Heat Shield Erosion
(Cameras E-023, E-024)

Figure 2.4.1 **Base Heat Shield Erosion**

Three erosion chips were noted on the base heat shield between SSME #1 and #3 and at least eight small chips were noted on the base heat shield on the left side near SSME #1 and #2. Base heat shield erosion has been seen on previous mission films. No follow up action has been requested.

ORIGINAL PAGE
COLOR PHOTOGRAPH

2.4.2 Orange Vapor

(Camera OTV-063, OTV-070, E-003, E-005, E-015, E-017, E-018, E-019, E-020, E-023, E-030, E-062, E-063, E-076)

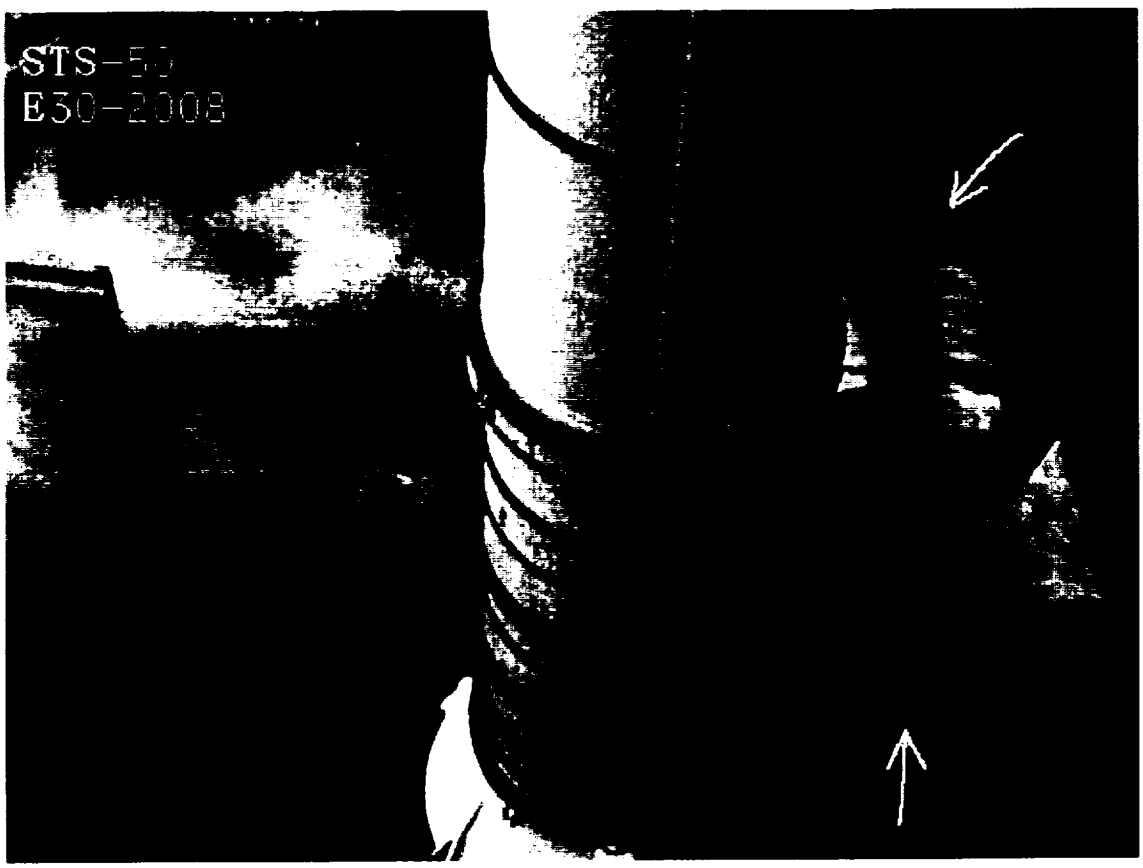


Figure 2.4.2 Orange Vapor Noted at SSME Startup

Orange vapor (possibly free-burning hydrogen) was seen below the SSMEs prior to SSME ignition. This vapor appeared to be similar to that noted on previous missions. The vapor was noted moving north beneath the body flap due to wind conditions at the pad just prior to SSME ignition.

2.4.3 Flashes in SSME Plumes at Engine Startup
(Cameras E-001, E-002, E-003, E-016)

Figure 2.4.3 Flash in SSME #1 Mach Diamond

Multiple orange colored flashes were seen in the SSME #1 and #2 exhaust plumes after SSME startup while the vehicle was still on the pad. Flashes in the SSME exhaust plumes at engine ignition has been seen on previous missions. No further analysis is expected.

2.0 Summary of Significant Events Analysis

2.5 Ascent Events

2.5.1 Loose RSRB Thermal Curtain Tape

(Camera E-005, E-009)

Figure 2.5.1 Loose RSRB Thermal Curtain Tape

A loose piece of thermal curtain tape was noted on the RSRB at liftoff (1.393 seconds MET). No follow up action is expected.

2.5.2 Flexing Motion of the RSRB Thermal Curtain
(Camera E-212)

Figure 2.5.2 **Flexing in RSRB Thermal Curtain**

A flexing motion of the RSRB thermal curtain was noted after the roll maneuver. Film E-212 was reviewed from the previous mission, STS-49, and the identical flexing motion of the RSRB thermal curtain was observed. The flexing motion is considered a normal event that is probably an optical effect caused by viewing through the engine exhaust gases. No further action is expected.

2.5.3 Flares in SSME Plume
(Cameras E-052, E-213, E-222, E-223, KTV-21A)

Multiple flares were seen in the SSME exhaust plume after liftoff on these long range tracking views. The flares were timed at 6.163, 14.890, 22.586, 27.872, 30.160, 34.322, and 36.992 seconds MET using cameras with digital timing. The flares on the films with binary coded timing

have been timed and the results are located in Appendix C. Flares during this time period have been seen on several earlier missions. No further analysis is expected.

2.5.4 Recirculation *(Task #1)*
(Cameras ET-207, ET-208, E-208, KTV-13)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all of the previous missions. For STS-50, the start of recirculation was observed at about 98 seconds MET and the end was noted at approximately 110 seconds MET on Camera E-208. See Appendix D for a summary of recirculation start and stop times for all missions since reflight.

Cameras on which recirculation was observed for STS-50

CAMERA	START (seconds MET)	STOP (seconds MET)
KTV-13	98	107
ET-207	-	-
ET-208	-	-
***E-208**	98	110

*** BEST VIEW OF RECIRCULATION**

NOTE: Intermittent LOV of the vehicle due to clouds prevented acquisition of specific start and stop times for recirculation on cameras ET-207 and ET-208.

2.6 DTO-0312 Analysis

2.6.1 Analysis of Onboard Photography of ET - Method 1 Umbilical Well Camera Evaluation *(Task #5)*

This photographic Detailed Test Objective (DTO) was performed using two 16 mm and one 35 mm umbilical well cameras. Good photographic coverage was obtained from LSRB separation; however, direct sunlight saturates the FOV after ET separation obscurring a major portion of all three films.

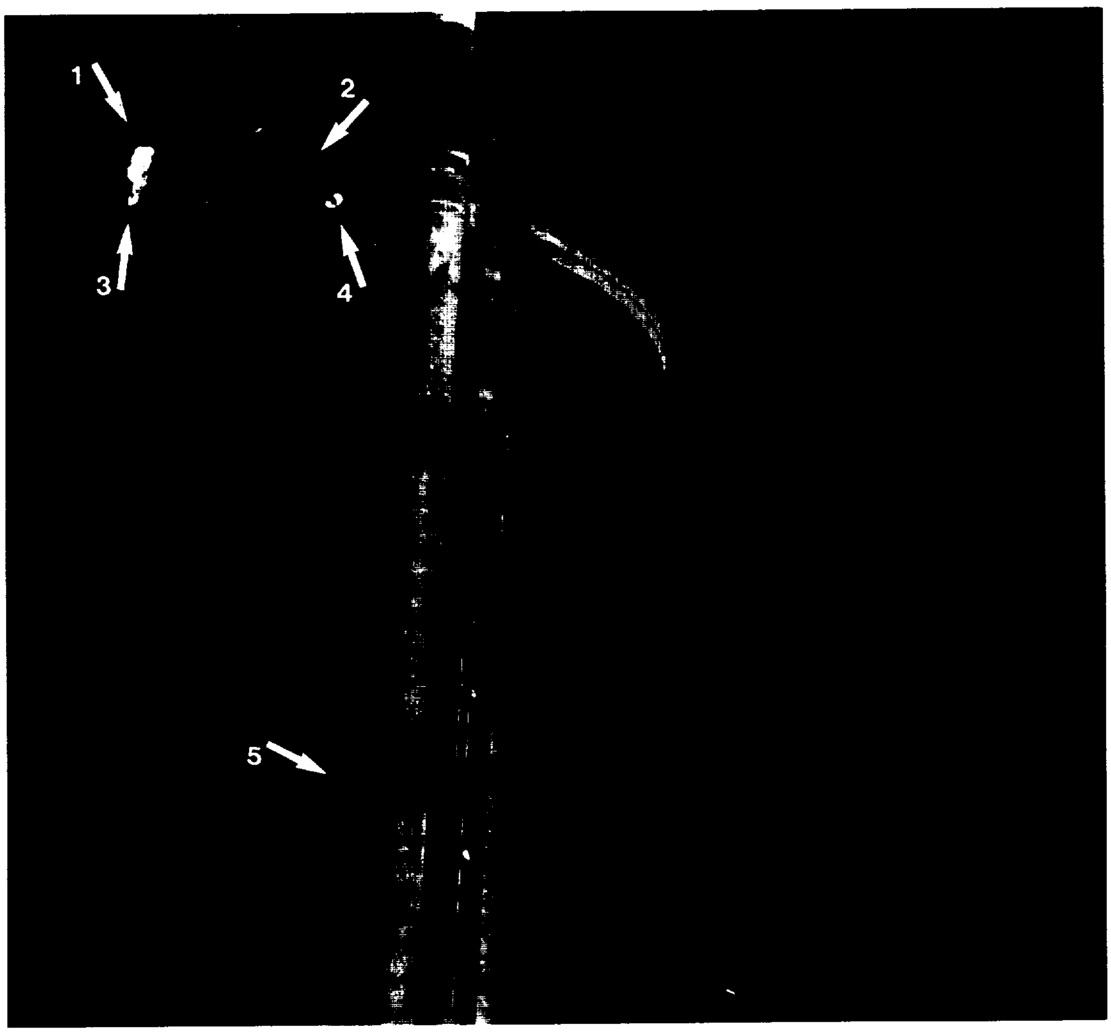


Figure 2.6.1 (A) Divot on the LH2 Intertank Interface Near the Bipod as Viewed by 35mm Camera in the Oxygen Umbilical Well

A rectangular shaped divot, measuring 26.5 inches in length and 9.3 (at its largest) to 4.9 inches in width, was seen on the LH2/Intertank flange at the PAL ramp at the base of the left leg of the forward ET/Orbiter attach bipod (arrow 1). The forward bipod is in the "standup" position (arrow 2). The gray colored area at the base of the divot appears to be the underlying ET structure (arrow

3). Shuttle engineers are reviewing this data as a possible source for the large debris strike observed near the LH2 umbilical well. Two other smaller divots are seen on this image; one near the right leg of the bipod (arrow 4) and the other near the LO2 feedline at a clamp below the LH2 intertank interface (arrow 5).

Multiple divots or eroded areas to the right of the ET LO2 umbilical, chipping of the TPS on the bracket over the LO2 feedline, press lines, TPS chipping on the aft ET/Orbiter attach brace and a white linear mark by the electric cable tray were seen further aft on the ET. The ET LO2 umbilical appeared to be free of ice, which is in contrast to the ET LH2 umbilical.

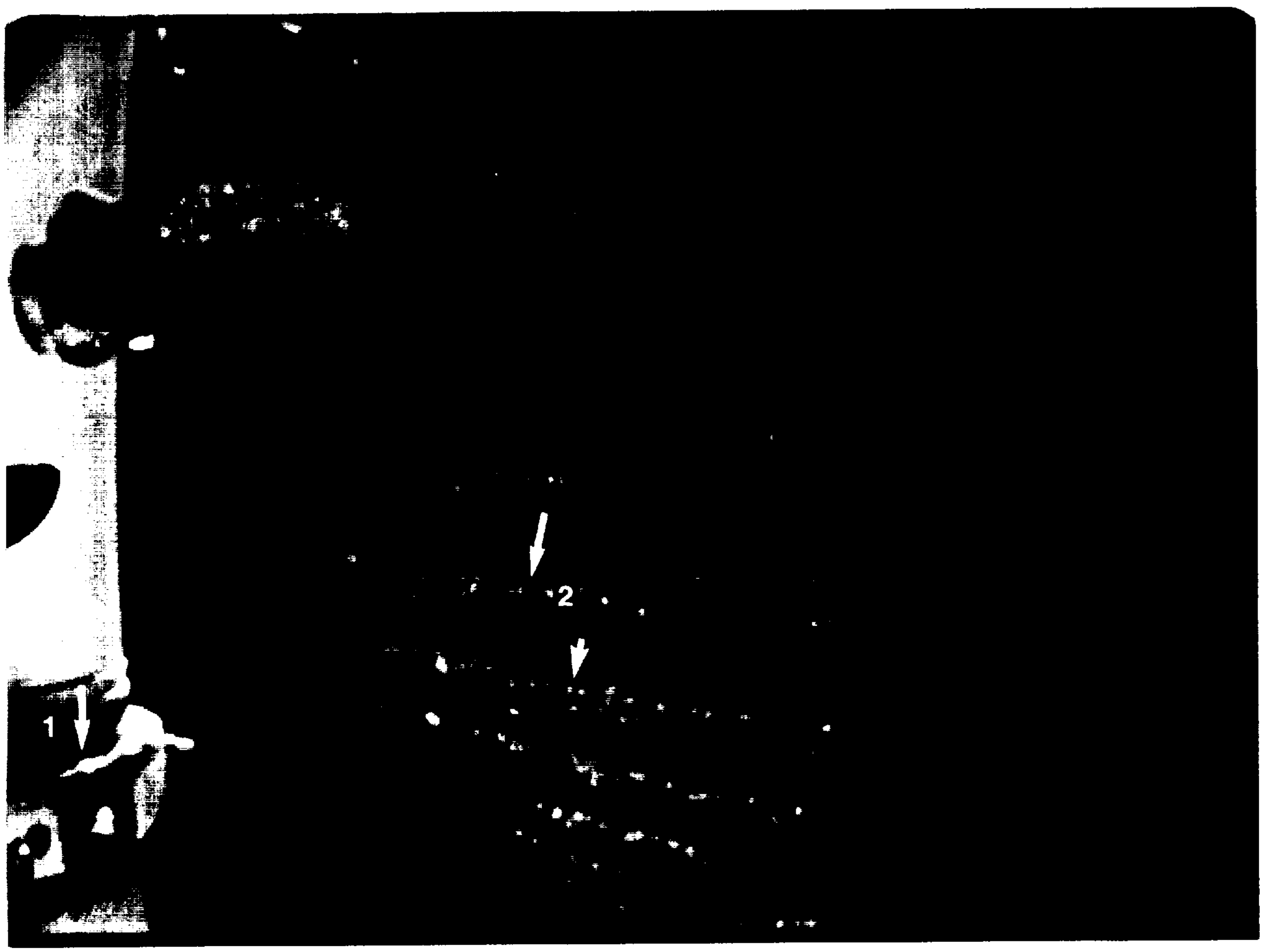


Figure 2.6.1 (B) LSRB Separation as Viewed by 16mm Umbilical Cameras

Figure 2.6.1 (B) was acquired shortly after SRB separation. Multiple small bright particles (probably TPS flakes) were in view prior to SRB separation. No anomalies were detected during the SRB separation sequence. A white substance, possibly ice, can be seen on the LSRB attach ring (arrow 1). Normal charring and erosion of the ET Thermal Protection System (TPS) can be

seen in the field of view (FOV) (arrow 2). Shortly after SRB separation, a piece of debris originating from the LH2 umbilical area traveled toward the LSRB and then fell aft.

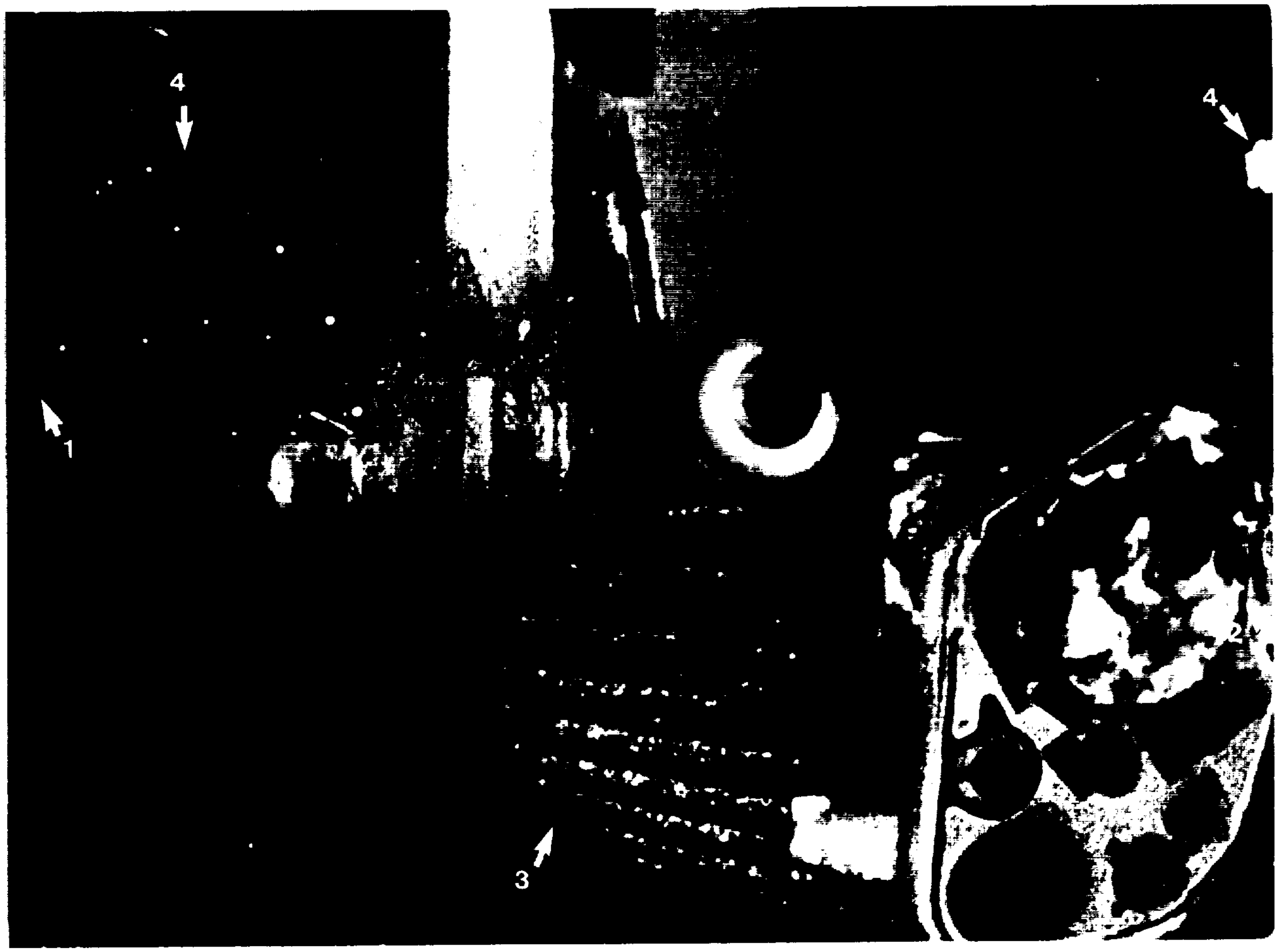


Figure 2.6.1 (C) Orange Vapor Visible to the Left of the ET as Viewed by 16mm Umbilical Cameras

The vapor observed from Figure 2.6.1 (C) is probably cause by the RCS firing (arrow 1). Ice was observed in the ET LH2 umbilical disconnect (arrow 2). Slight erosion of the ET aft dome TPS was observed (arrow 3). Multiple pieces of white debris (probably ice) traveled through the FOV before, during and after ET separation (arrow 4). Shortly after ET separation, the sun saturates the FOV.

ORIGINAL PAGE
COLOR PHOTOGRAPH

2.6.2 Analysis of Onboard Photography of ET - Method 2 Onboard ET Photography Analysis *(Task #6)*

(STS-50-71-001 through STS-50-71-089)

Eighty-nine 70 mm Hasselblad frames were reviewed. The first sixty-five frames were acquired while the W-8 UV filter was still mounted in the overhead window. These frames were underexposed. None of the 70 mm photography showed divots in the ET SOFI area or on the LH2 and LO2 intertank interfaces. No mensuration analysis was performed.

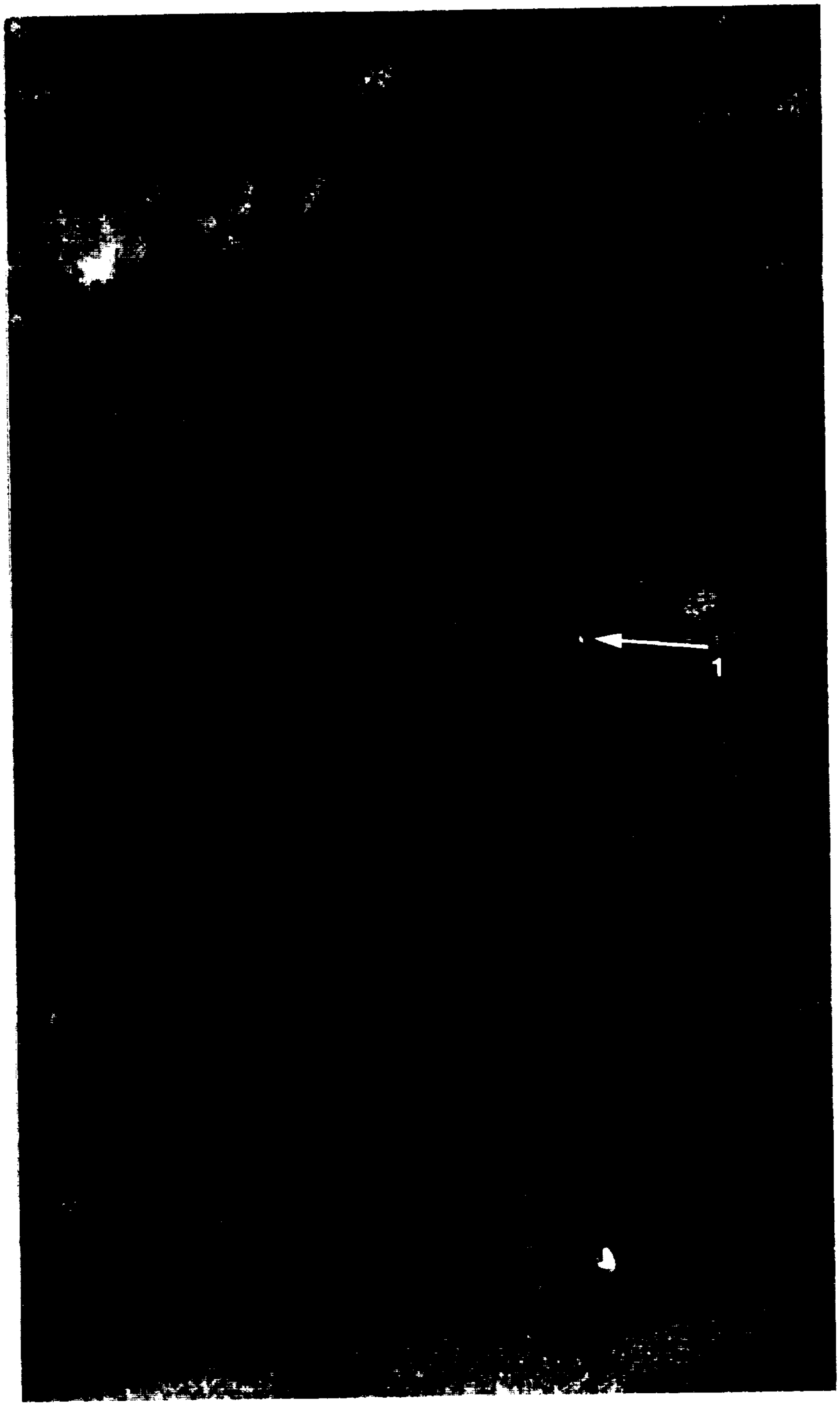


Figure 2.6.2 **View of -Y Side of ET (STS-50-71-004)**

2.0 Summary of Significant Events Analysis

The -Y side of the ET can be seen in Figure 2.6.2. This photograph was taken approximately 5 minutes 40 seconds after ET separation. The ET TPS appears to be in good condition. The bright area by the left leg of the forward bipod (arrow 1) is the PAL ramp that was seen to be damaged on the review of the 35mm umbilical well camera film. The SRB burn scars on the ET Ogive appears normal.

2.7 Landing Events

No anomalies were detected during the landing of STS-50. The following analyses have been performed as part of the normal mission operations. Drag chute events have been timed. Further analysis will not be performed because KSC cameras do not provide sufficient location and pointing information. Located in Appendix D Task #10 is the KSC report of where the pieces of the drag chute system landed on the runway.

2.7.1 Elevon Deflection During Landing *(Task #11)* *(Camera EL-009)*

The JSC Flight Control Office/EG311 requested that a photographic analysis be performed on the landing views of the orbiter in order to determine if there was a measurable difference in the left and right outboard elevon positions. Telemetry data indicated up to a 3 degree difference in the left and right elevons during the landing approach. Camera EL-009, which is a view of the aft end of the orbiter during landing, was used for the analysis. Points on the right wing inboard and outboard elevons were measured and compared to the points taken on the left wing inboard and outboard elevon during the final approach and again after main gear touchdown when the elevon was at the maximum up deflection. The times for the start and stop frames for each sequence were read from the binary code. The raw data was scaled to the orbiter and submitted to the JSC Flight Control Office/EG311 for comparison against the telemetry data. The timing information is located Appendix C and the positional information is located in Appendix D Task #11.

2.7.2 Sink Rate Analysis *(Task #3)*

2.7.2.1 Landing Sink Rate Using Film *(Cameras EL-009)*

Camera EL-009 film was used to determine the sink rate of the main gear. Both the right and left inboard tires were used to scale the measurements. Data was gathered for 1.058 seconds prior to landing through touchdown. Six reference points on every other frame over this time period were digitized. The reference points consisted of the top and bottom of both the right and left main gears and the two points on the runway immediately beneath the main gear wheels. The raw data was corrected for in each observation. The distance between the bottom of the main gear wheels and the runway was computed. A linear regression was applied on the normalized vertical distance versus time data to determined the actual sink rate. The sink rate was determined to be 1.8 feet/second which is well within the current threshold limits.

Nose gear touchdown occurred approximately 18 seconds after main gear touchdown which is longer than normal. No STS-50 landing views were sufficient to calculate an accurate nose gear sink rate.

Graphs depicting the above data are located in Appendix D Task #3.

2.7.2.2 Landing Sink Rate Using Video
(Camera KTV-33)

Data from camera KTV-33 was used to determine the sink rate of the main gear. The outer right main landing gear wheel was used as a reference scale for each frame. The position of the main gear as a function of time was found by taking the difference between the raw vertical positions of the main landing gear and a fixed point near the edge of the runway. The data was collected over 21 frames separated by 1/15 seconds (ie. every other frame was used) from approximately one second before touchdown until touchdown. Using an average scale, these differences were converted to feet. A least squares regression line was calculated from the data and the slope was used as the average sink rate. The sink rate was found to be 3.1 feet/second.

The sink rate for the nose gear was also calculated using 21 frames digitized from camera KTV-33 (These frames were also separated by 1/15 seconds). A linear regression of the data was calculated in the same manner as above, except that instead of using a point near the runway as a control the nose wheel distances were measured with respect to the position of the nose wheel in the first frame. (This method is somewhat less accurate than using a control point, but no good horizontal control point could be found.) The slope of this line was used as the sink rate and was found to be 1.87 feet per second.

See Appendix D Task #3 for details.

Results from the film analysis are considered better than video because of the higher spatial resolution. The quantization error inherent in the use of the video makes this analysis insufficient to meet the 0.1 feet per second precision required by the OMSRB.RCNSD500002DV51.P.001.

2.7.3 Drag Chute Performance *(Task #10)*
(Cameras EL-009, Handheld Mavica)

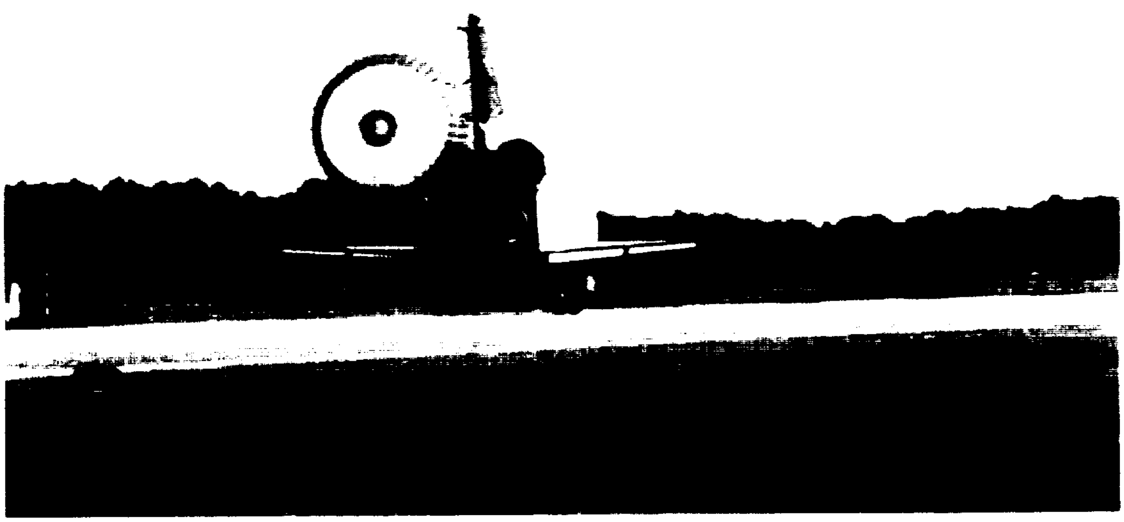


Figure 2.7.3 Full Inflation of Drag Chute in Disreefed Configuration

STS-50 was the second test of the Space Shuttle landing drag chute and the first time this functional test was performed on Columbia (OV-102). All of the events occurred as expected. The various stages are drag chute initiation, pilot chute inflation, bag release, chute inflation in reefed configuration, disreefing initiation, full chute inflation and chute release. The times for these events are located in Appendix C and are summarized in Appendix D Task #10.

2.7.4 Post Landing Inspection of Damage to the Orbiter
(Handheld Mavica and Video Cameras)

The post landing walk down of the orbiter revealed that the vehicle sustained a total of 98 strikes, of which 27 had a major axis of greater than one inch. The amount and severity of the impact damage is considered higher than normal and the number of strikes greater than one is higher than normal.

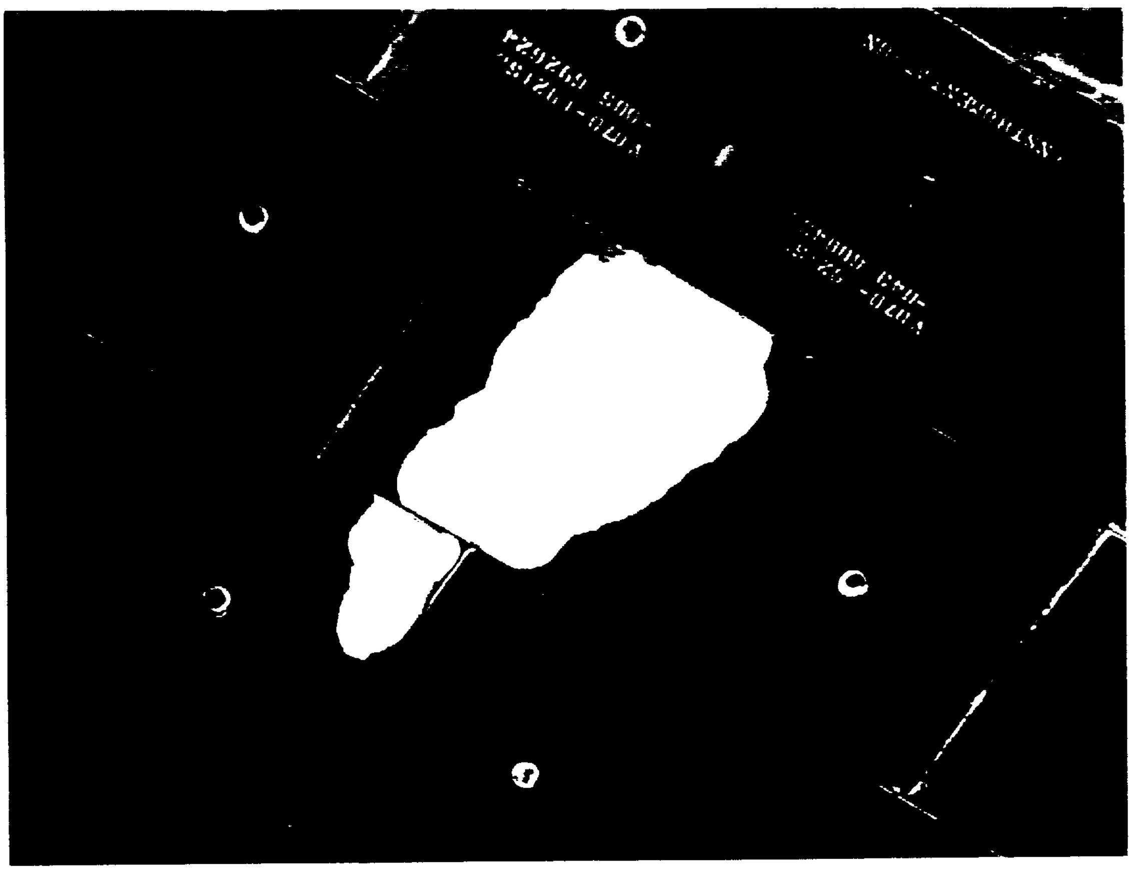


Figure 2.7.4 (A) Large Impact Strike on the Lower Surface of the Orbiter

The most significant damage to the lower surface of the orbiter measured 9"x4.5"x0.5". This debris spanned over three tiles between the LH2 ET/Orbiter umbilical and the left inboard elevon. The divot seen on the ET PAL ramp by the left forward bipod ET/Orbiter attach on the 35mm umbilical camera film is being studied by shuttle engineers as a possible source for the Orbiter tile damage shown above.

Figure 2.7.4 (B) Damage to the DMHS Blanket #3

Other damage to the vehicle included damage to the DMHS blankets which surround SSMEs #1 and #3. Damage to DMHS blanket has been seen on the post landing images taken on previous missions.

2.7.5 Post Landing Inspection of Debris Found on Runway
(Handheld Mavica and Video Cameras)

Figure 2.7.5 **Drag Chute Door Runway Strikes**

The arrows in Figure 2.7.5 shows the marks left on the runway by the drag chute door after chute initiation. The marks are to the right of the centerline as expected. This is different than the position of the door for STS-49 which went to the left of the centerline. The KSC report of the runway location of the drag chute assembly is located in Appendix D Task #10. Other debris found on the runway was an expended detonator/electrical connector (2 pieces) from the umbilical separation system.

Appendix B. MSFC Photographic Analysis Summary

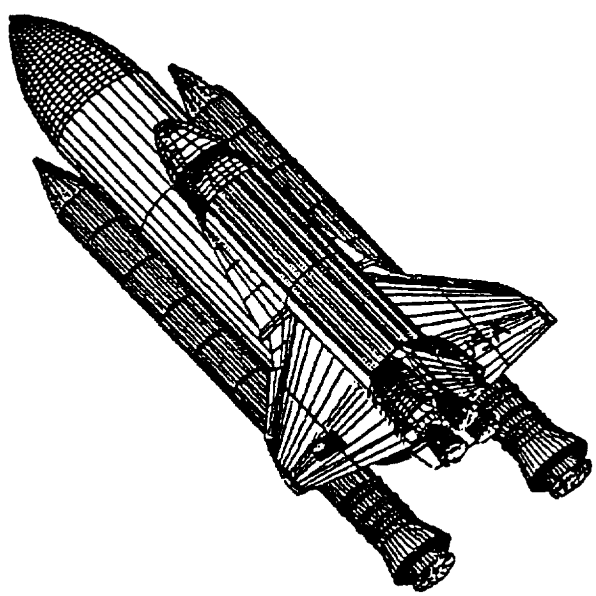
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-50



National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

Reply to Attn of: EP55 (92-69)

July 31, 1992

TO: Distribution

FROM: EP55/T. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-50

Enclosed is the Engineering Photographic Analysis Report for the Space Shuttle Mission STS-50. For additional copies, or for further information concerning this report, contact Tom Rieckhoff at 544-7677, or Darlene Busing/Rockwell, 971-3174.

Tom Rieckhoff

Tom Rieckhoff
Performance Analysis Branch

Enclosure

Distribution: See page 2

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-50

FINAL

PREPARED BY:

J. HIXSON, D. BUSING, B. VIGER, W. LANGLOIS
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:

Ed Jackson

ED JACKSON
MANAGER, LAUNCH AND FLIGHT OPERATIONS/ROCKWELL/HSV

APPROVED BY:

Tom Rieckhoff

T. RIECKHOFF, MSFC/EP55
B. LINDLEY-ANDERSON, MSFC/EP55

STS-50 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

July 31, 1992

I. INTRODUCTION

Space Shuttle Mission STS-50, the twelfth flight of the Orbiter Columbia, was conducted June 25, 1992 at approximately 11:12 A.M. Central Daylight Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-50 included, but were not limited to the following.

a. Overall facility and Shuttle vehicle coverage for anomaly detection
b. Verification of cameras, lighting and timing systems
c. Determination of SRB PIC firing time and SRB separation time
d. Verification of Thermal Protection System (TPS) integrity
e. Correct operation of the following:
   1. Holddown post blast covers
   2. SSME ignition
   3. LH2 and LO2 17" disconnects
   4. GH2 umbilical
   5. TSM carrier plate umbilicals
   6. Free hydrogen ignitors
   7. Vehicle clearances
   8. GH2 vent line retraction and latch back
   9. Vehicle motion

There were two special test objectives for this mission.

a. SRB holddown post shoe rotation quantification
b. DTO-0312, ET photography after separation

III. CAMERA COVERAGE ASSESSMENT:

Film was received from sixty of sixty-one requested cameras as well as video from twenty-three of twenty-three requested cameras. The following table illustrates the camera data received at MSFC for STS-50.

CAMERA DATA RECEIVED FOR STS-50

	16mm	35mm	70mm	Video
MLP	26	0	0	3
FSS	7	0	0	3
Perimeter	3	3	0	6
Tracking	0	15	0	11
Onboard	4	1	1	0
Totals	40	19	1	23

A detailed individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

Photographic coverage of STS-50 ranged from good to poor. Coverage from the trackers was limited due to cloud coverage. Camera E-12 experienced a timing problem. The timing resets to zero and continues to stay there throughout liftoff. Cameras E-4, E-28 and E-36 experienced some camera jitter.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly, but did not record water impact. Also, the astronauts carried a 70mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. Two 16mm motion picture cameras and one 35mm still camera were flown on this mission in the Orbiter's umbilical wells to record the SRB and ET separation events.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: pad debris rising and falling as the vehicle lifts off; debris induced streaks in the SSME plume; ice falling from the 17" disconnect and umbilicals and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors, purge barrier material and SRB thermal curtain tape.

b. SRB Holddown Post M-4 Stud Hang-up:

Figure one is a frame of film taken from camera E-7 showing holddown post M-4 stud hang-up. The stud appears to remain fully extended until the SRB aft skirt clears the extended holddown post stud. The stud also pulled loose several pieces of EPON shim material.

c. Loose Thermal Curtain Tape:

Figure two is a frame of film taken from camera E-52 showing a piece of loose thermal curtain tape on the right hand SRB.

d. Pad Debris at T+1.9 Seconds:

Figure two also shows a piece of debris which comes from the right hand SRB blast hole. This debris was seen on several cameras. It rises from the blast hole and travels away from the vehicle without impacting the vehicle.

e. ET TPS Divots:

Figure three is a film frame taken from the 35mm umbilical well camera showing the aft portion of the ET after separation. Visible in the photo are several TPS divots. The large divot appearing between the 17 inch LO2 disconnect and the Orbiter attach point has been determined to be approximately 8.5 inches at the longest dimension. Figure four is a film frame from the 35mm umbilical well camera showing the forward portion of the ET after separation. Several TPS divots are also visible in this photo. The large divot appearing near the bipod is determined to be 7 x 21 inches.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times were determined from cameras which view the SRB holddown posts numbers M-1, M-2 and M-6. These cameras record the explosive bolt combustion products.

POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	177:16:12:23.007
M-2	E-8	177:16:12:23.008
M-6	E-13	177:16:12:23.005

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 31.7 inches. Figure five is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera E-79.

c. SRB Separation Time:

SRB separation time for STS-50 was determined to be 177:16:14:29.34 UTC taken from camera E-208.

d. SRB Holddown Post Shoe Rotation Study:

A study was performed on this mission to determine the aft skirt/shoe rotation effects at T-Zero due to the radial biasing of the MLP holddown post to 0.060 inches.

Cameras EX1, EX4, and E-27 were used to provide close-in coverage of the shoes and holddown posts M-1, M-3, and M-5, respectively. However, due to excessive camera vibration, rotation data could not be gathered for holddown post M-7.

Figure six shows the locations of the cameras and holddown posts and direction of "horizontal motion" relative to the attached plots.

Figures seven and eight show the target positions of the motion data taken relative to a stationary target on the MLP. Figure seven represents posts M-1 and M-5. Figure eight represents post M-3.

The following table provides the RMS data accuracy for each post measured in inches.

Post	Horizontal	Vertical
M-1	+.011	+.013
	-.021	-.014
M-3	+.011	+.014
	-.009	-.017
M-5	+.015	+.025
	-.019	-.029

The motion data are presented in figures nine through eighteen These data have been filtered to remove the noise from the interactive digitization process.

Figure 1

Holddown Post M-4 Stud Hang-up

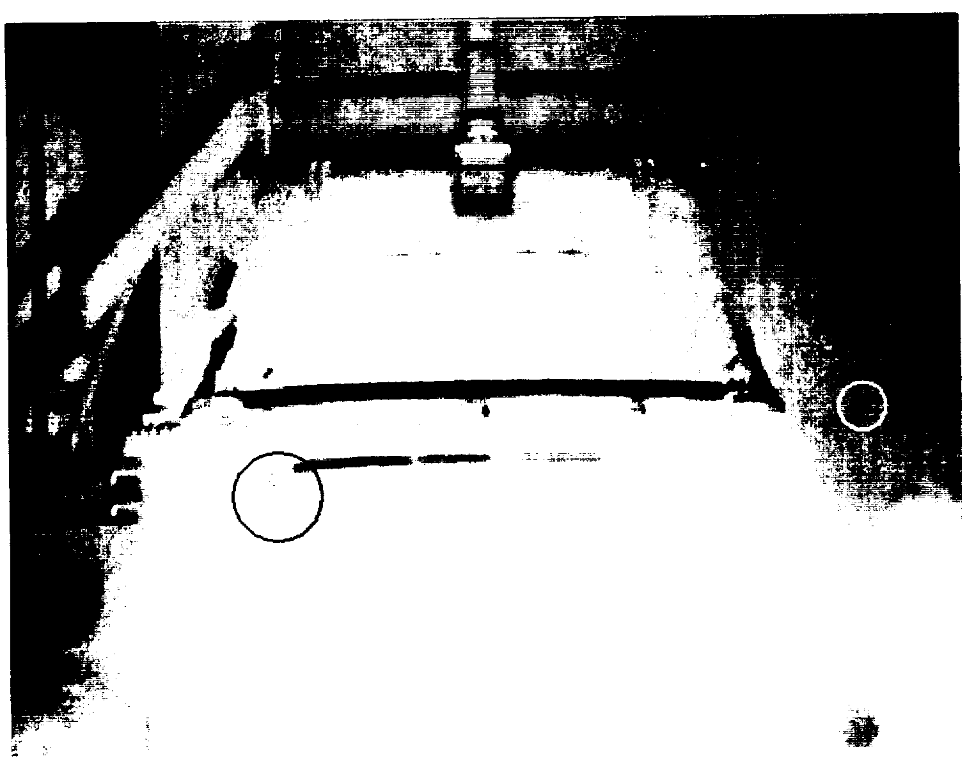


Figure 2

Loose Thermal Curtain Tape

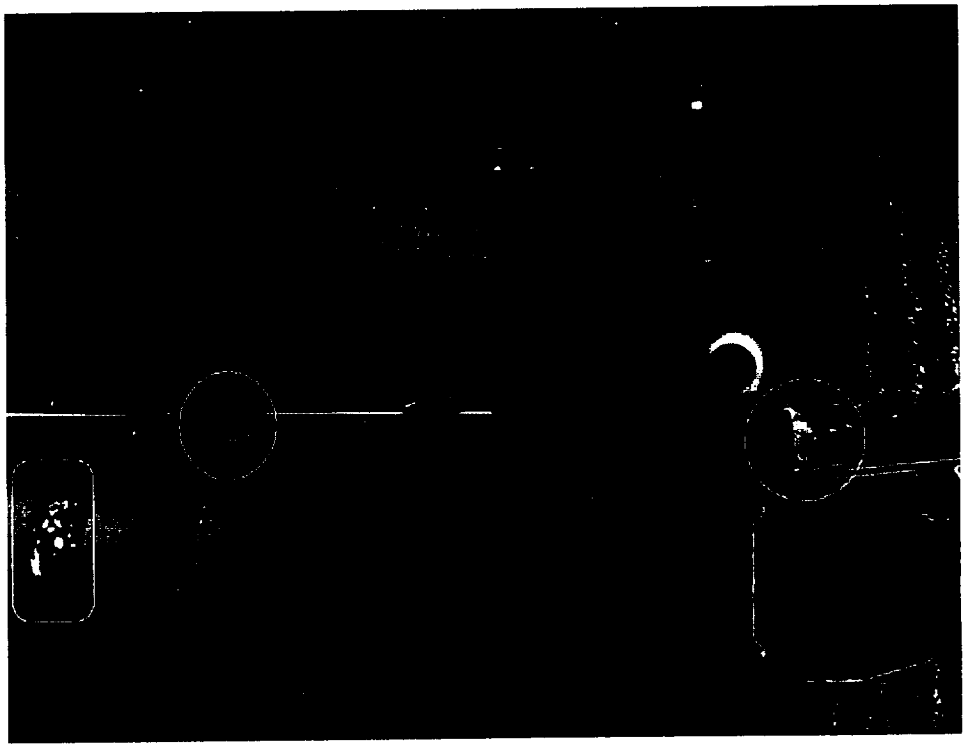


Figure 3

TPS Divots

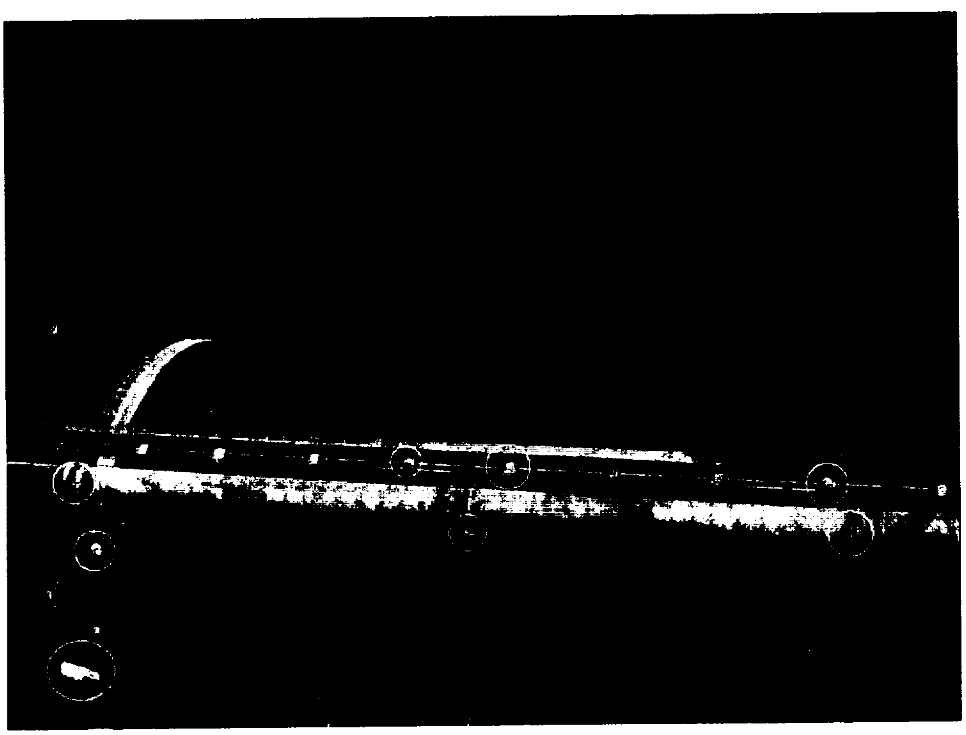


Figure 4

TPS Divots

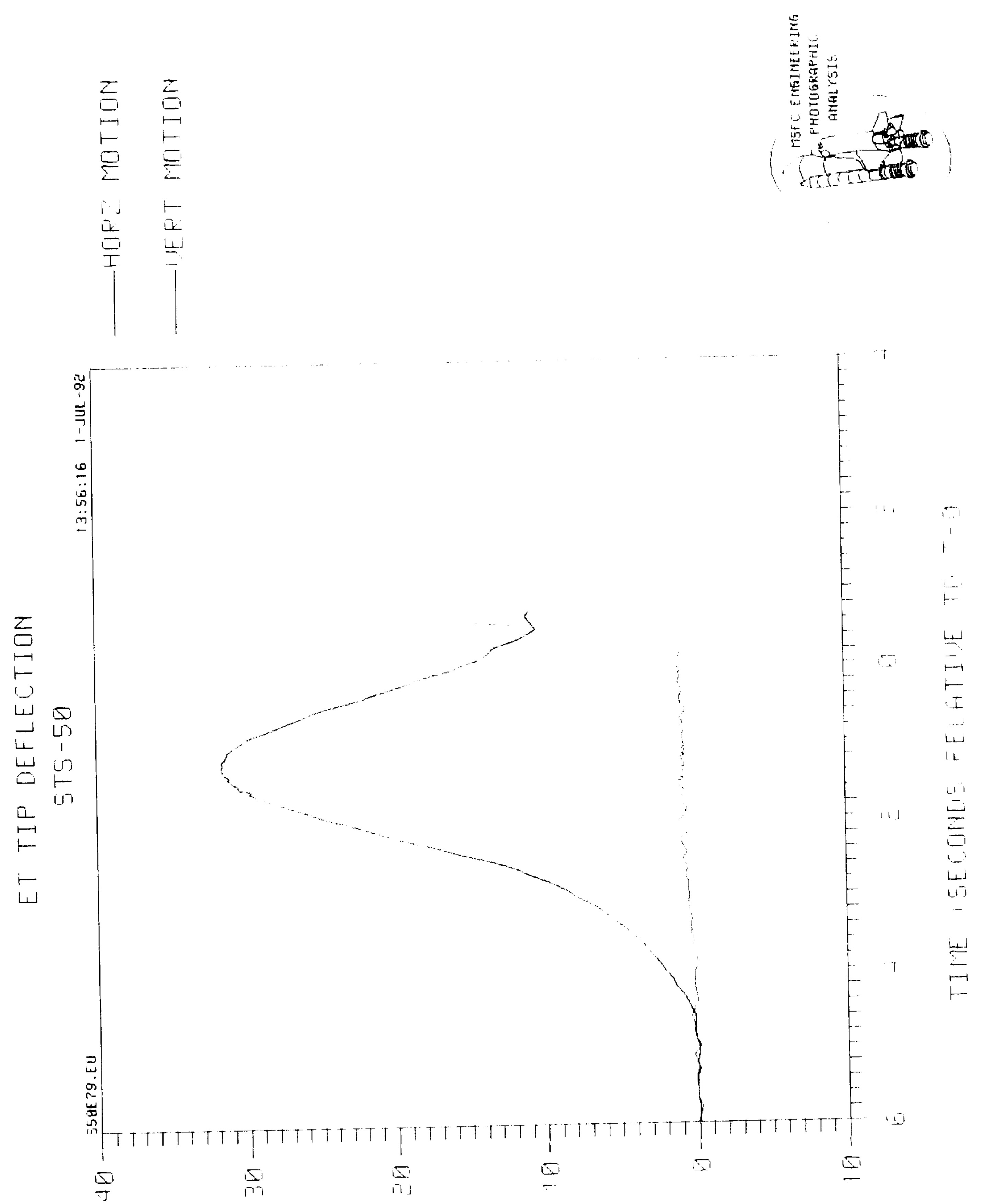


Figure 5

ORIGINAL PAGE
COLOR PHOTOGRAPH

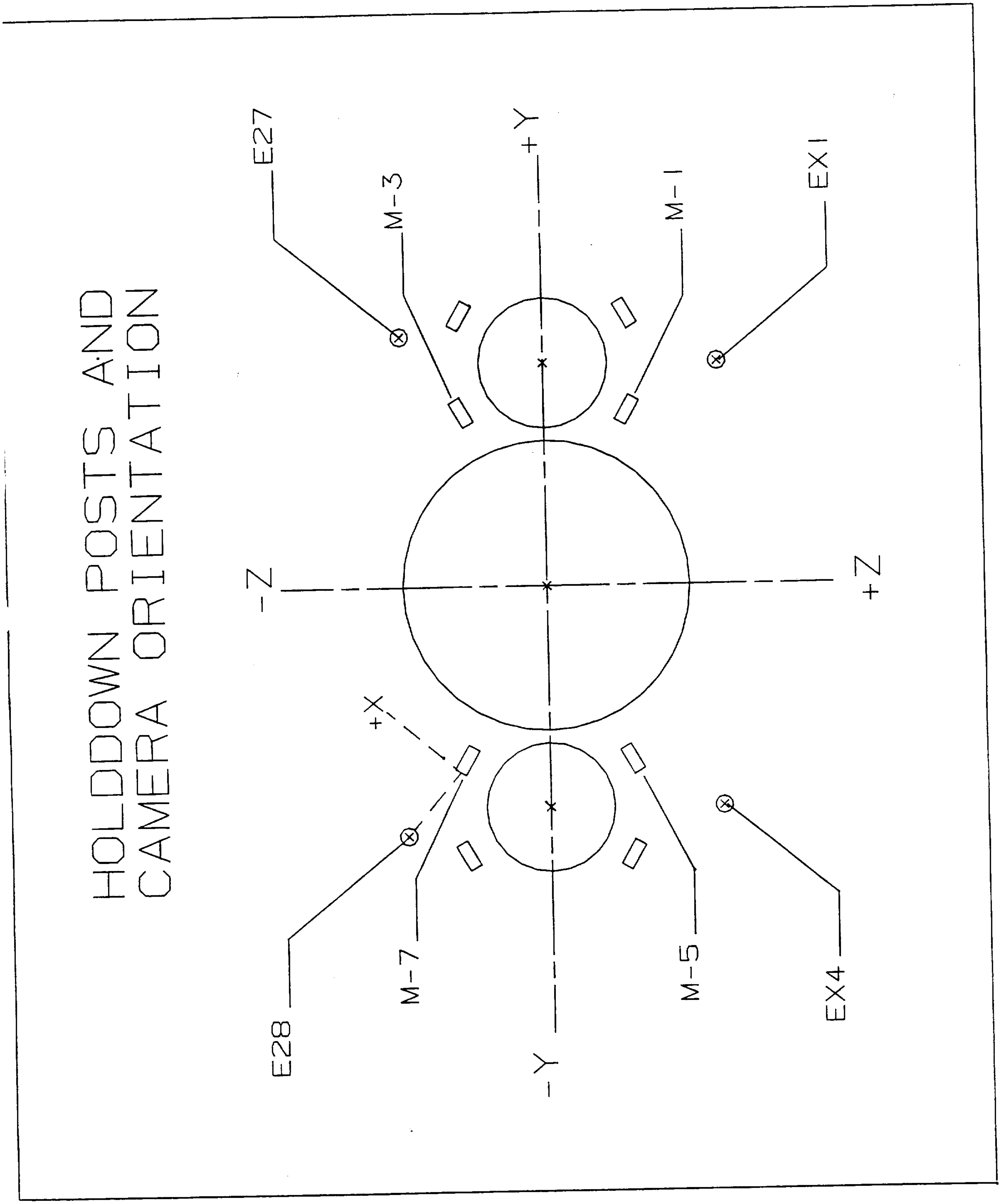


Figure 6
Camera Locations

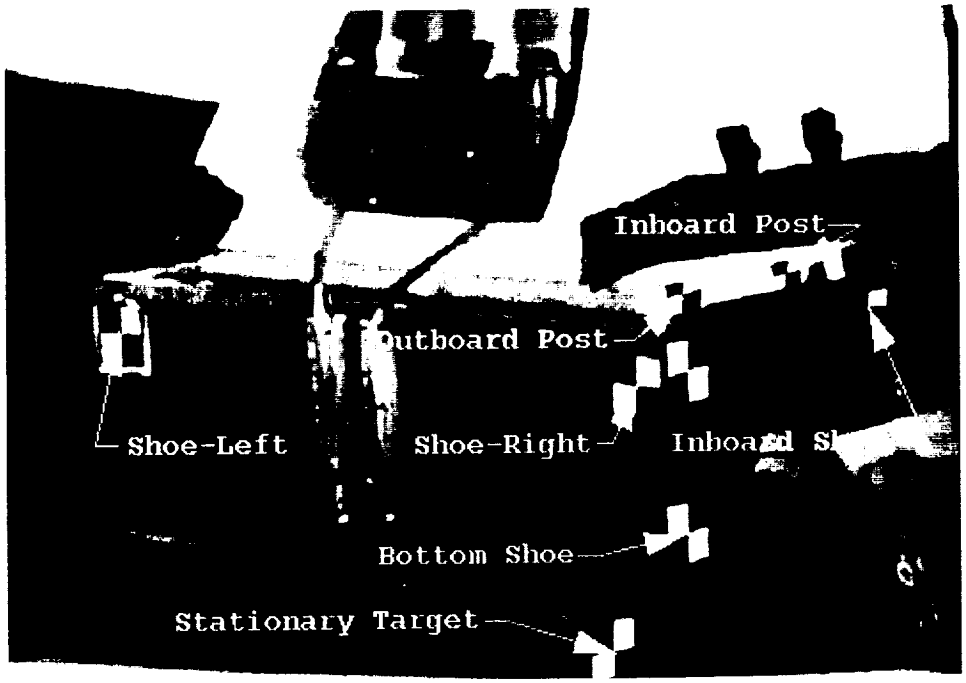


Figure 7

Target Positions of Holddown Posts M-1 and M-5

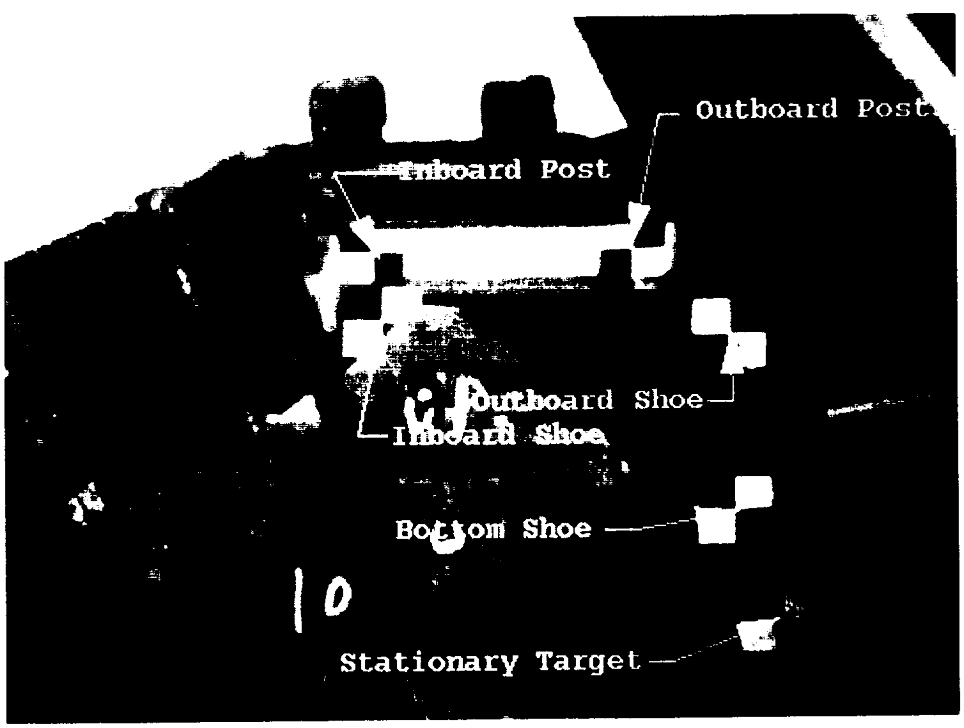


Figure 8

Target Positions of Holddown Post M-3

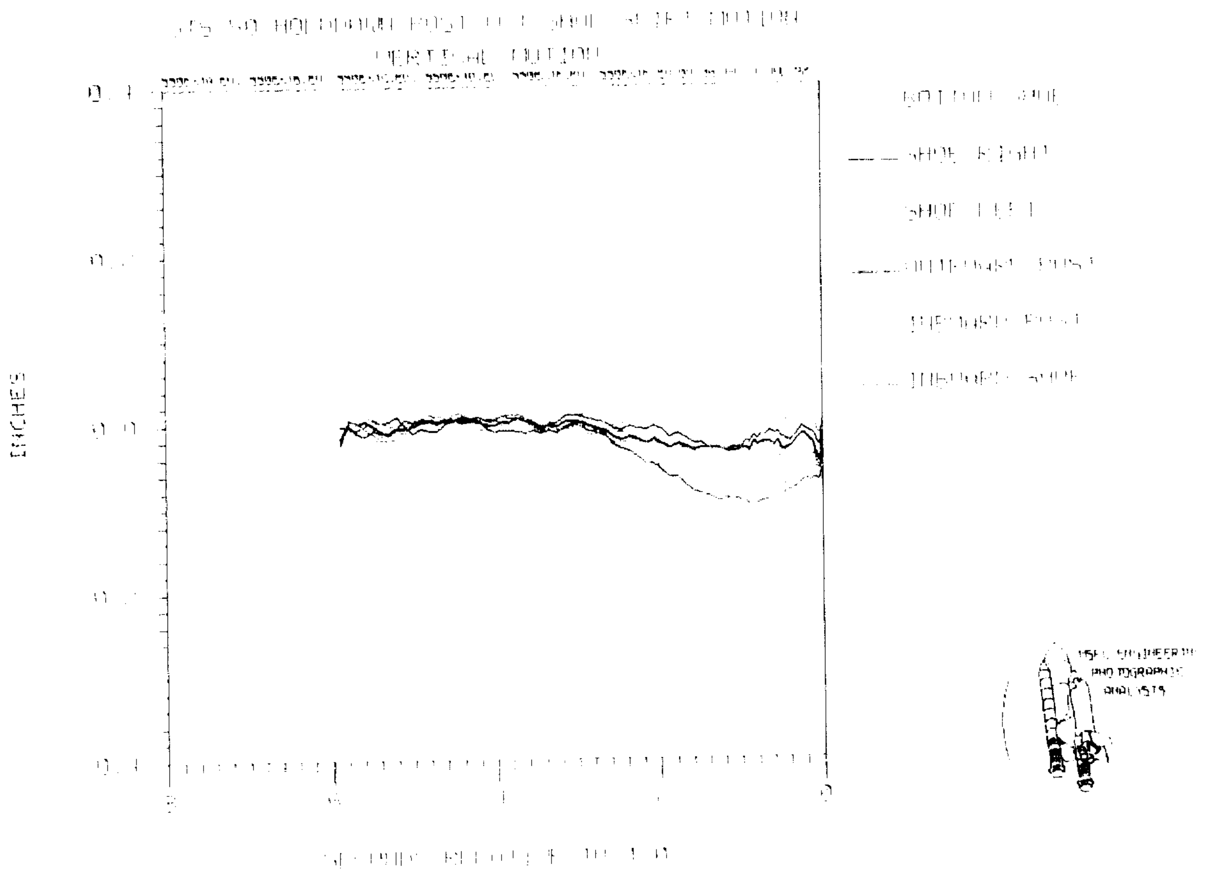


Figure 9

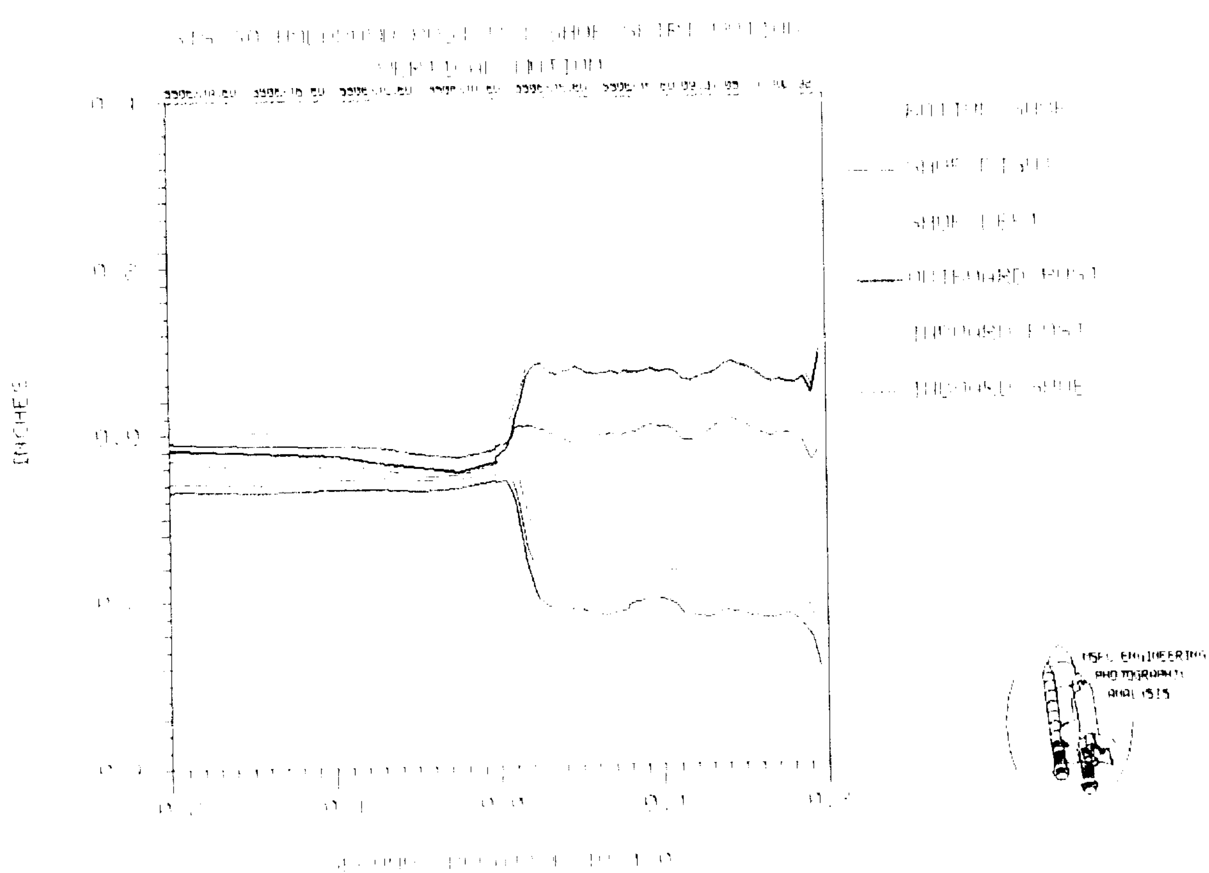


Figure 10

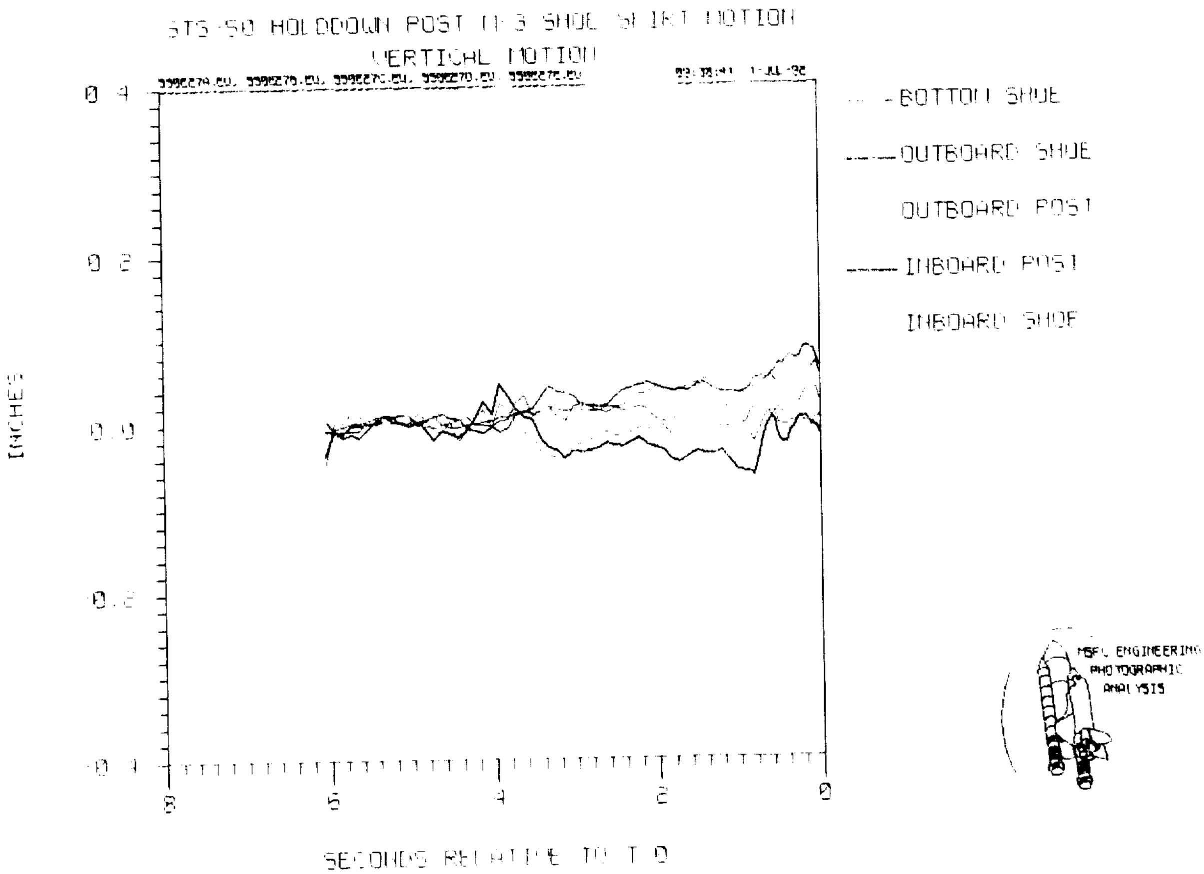


Figure 11

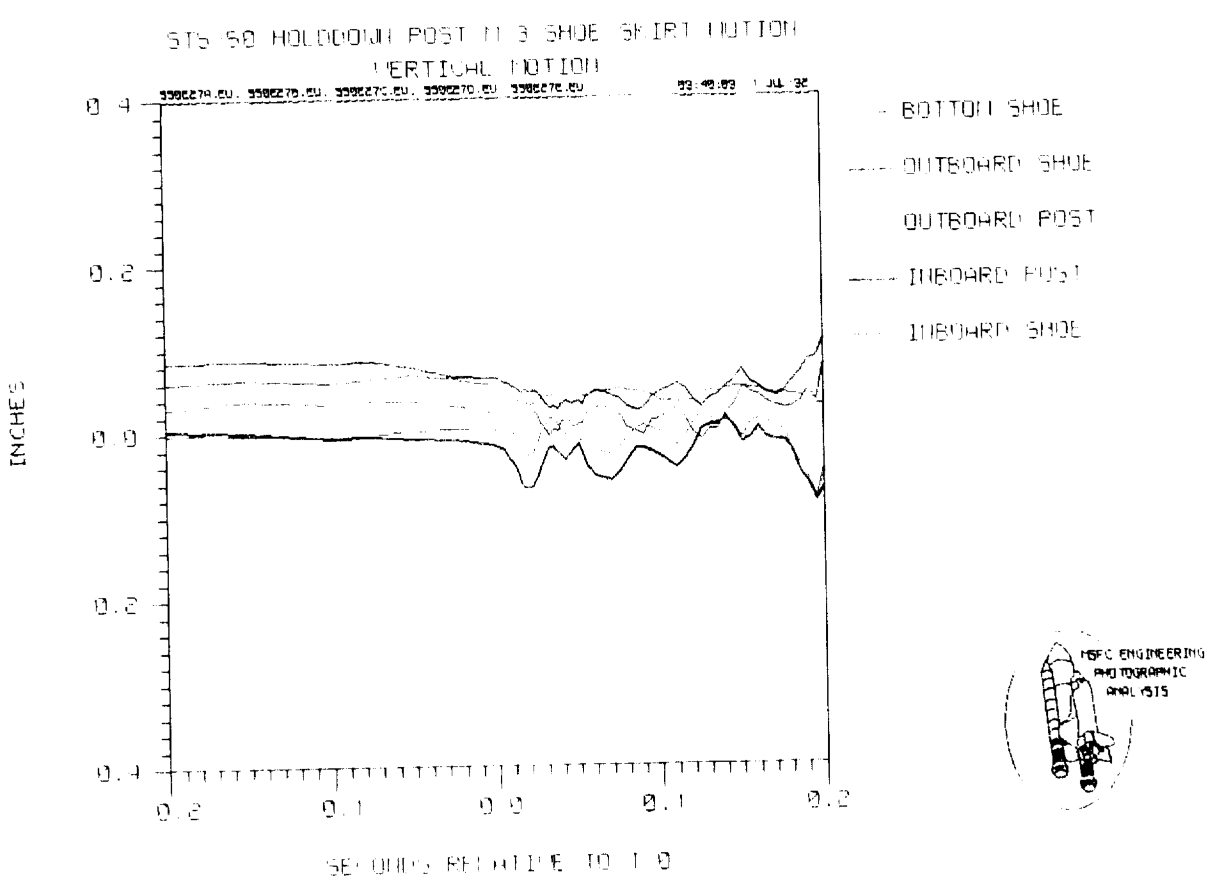


Figure 12

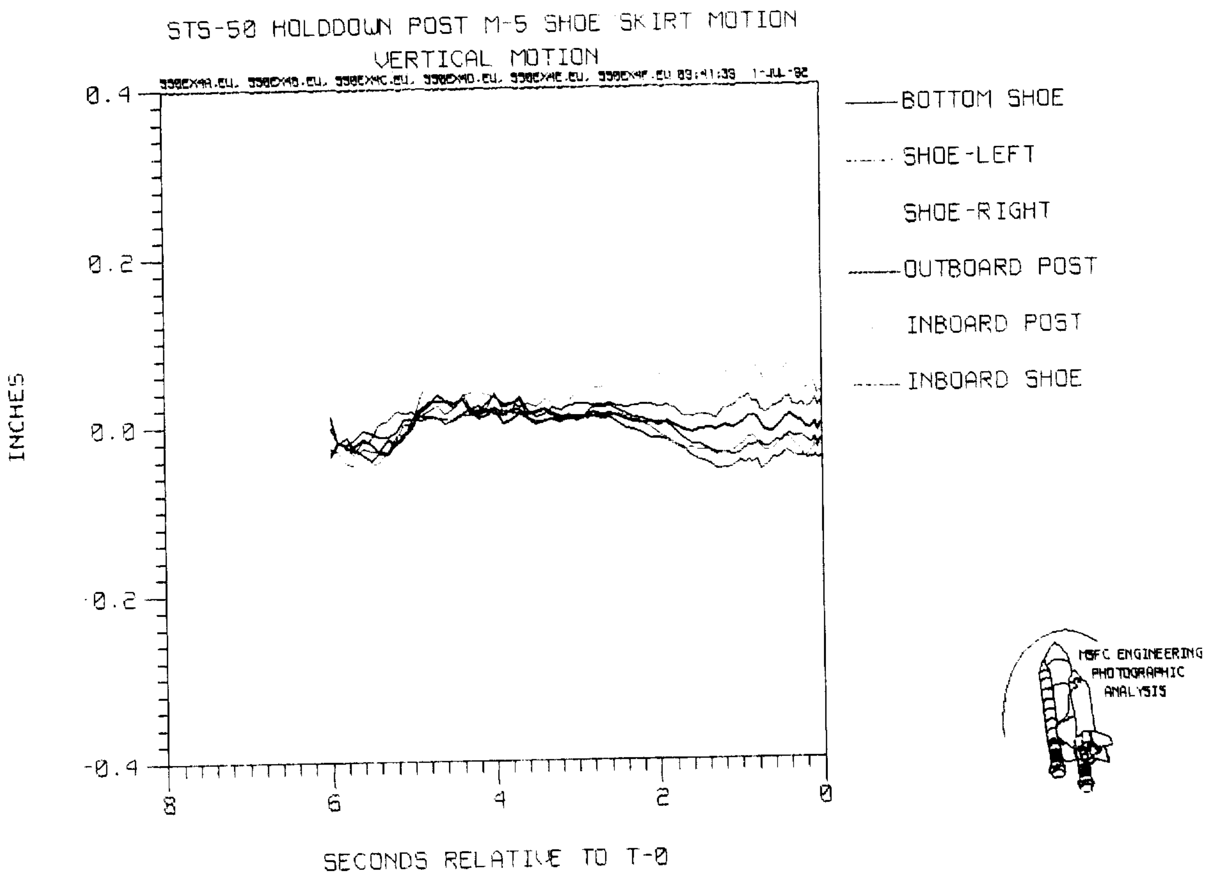


Figure 13

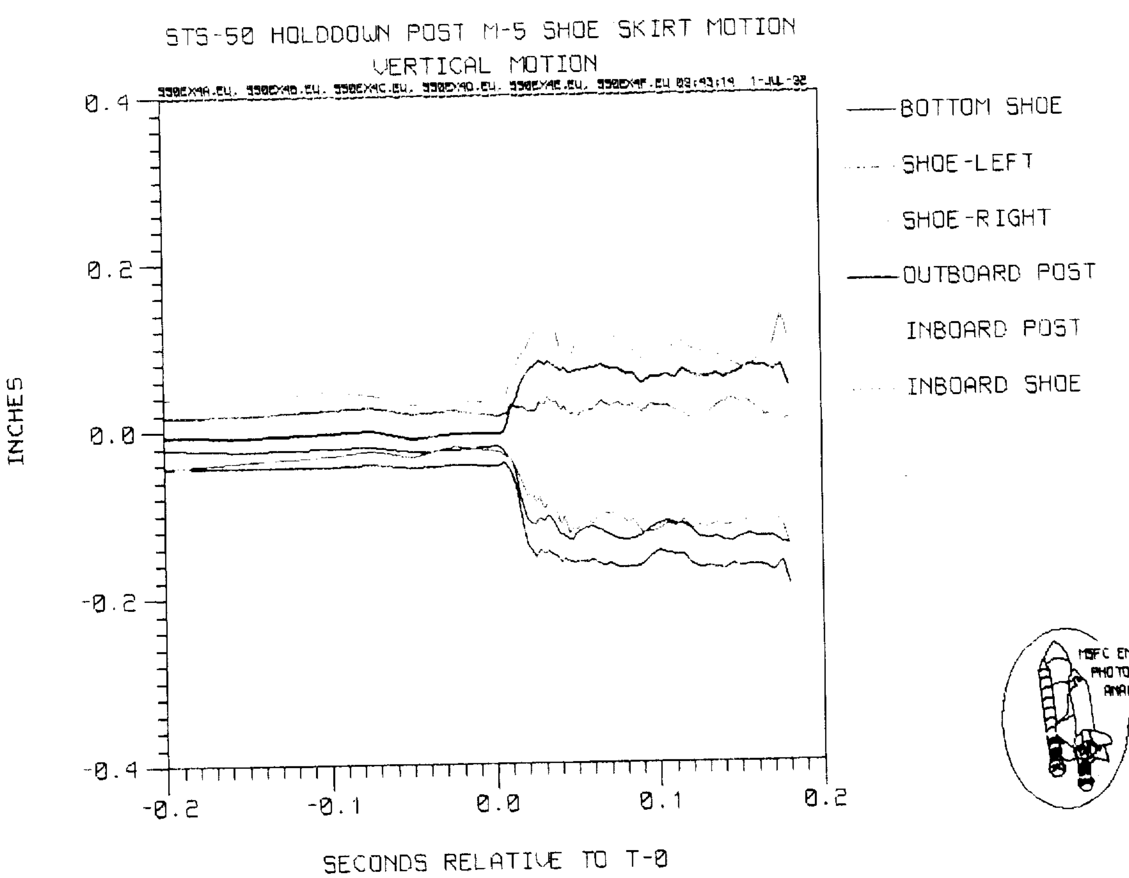


Figure 14

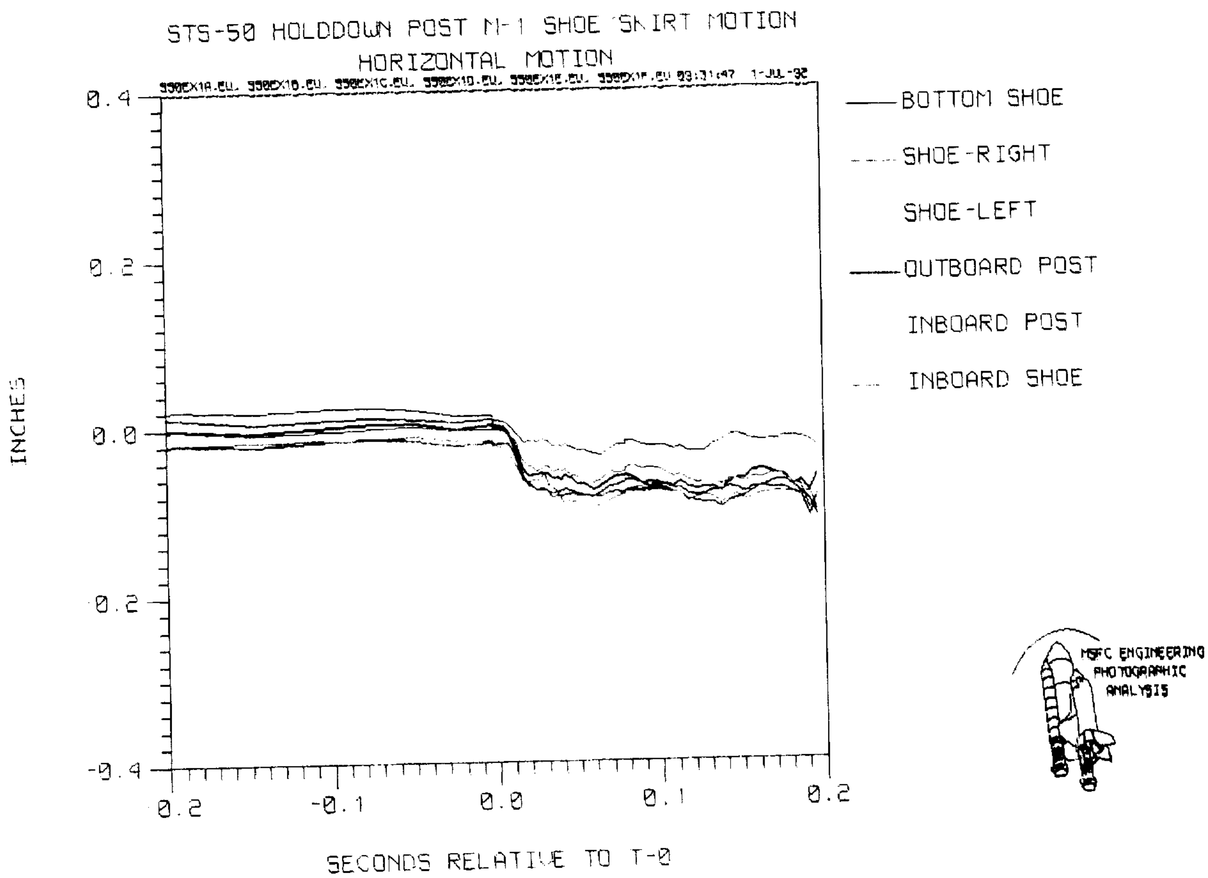


Figure 15

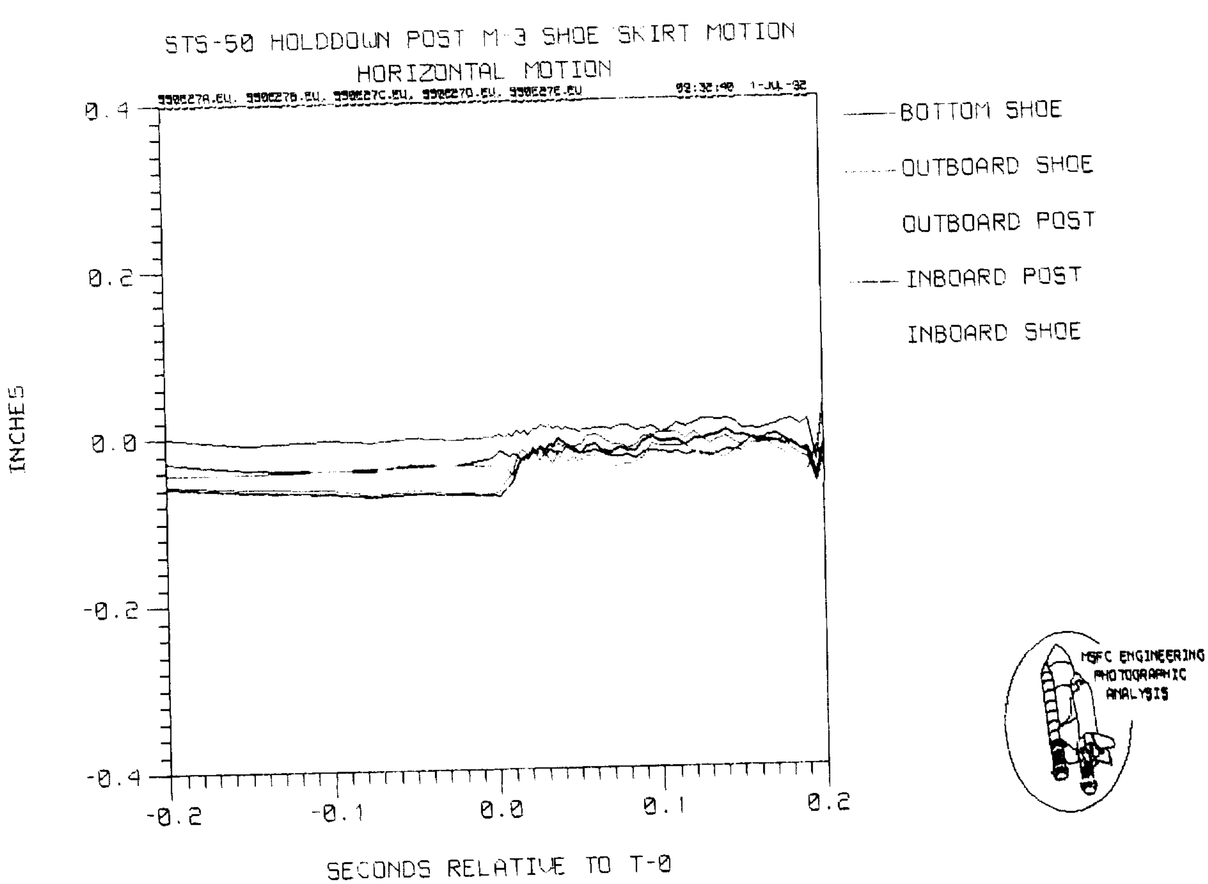


Figure 16

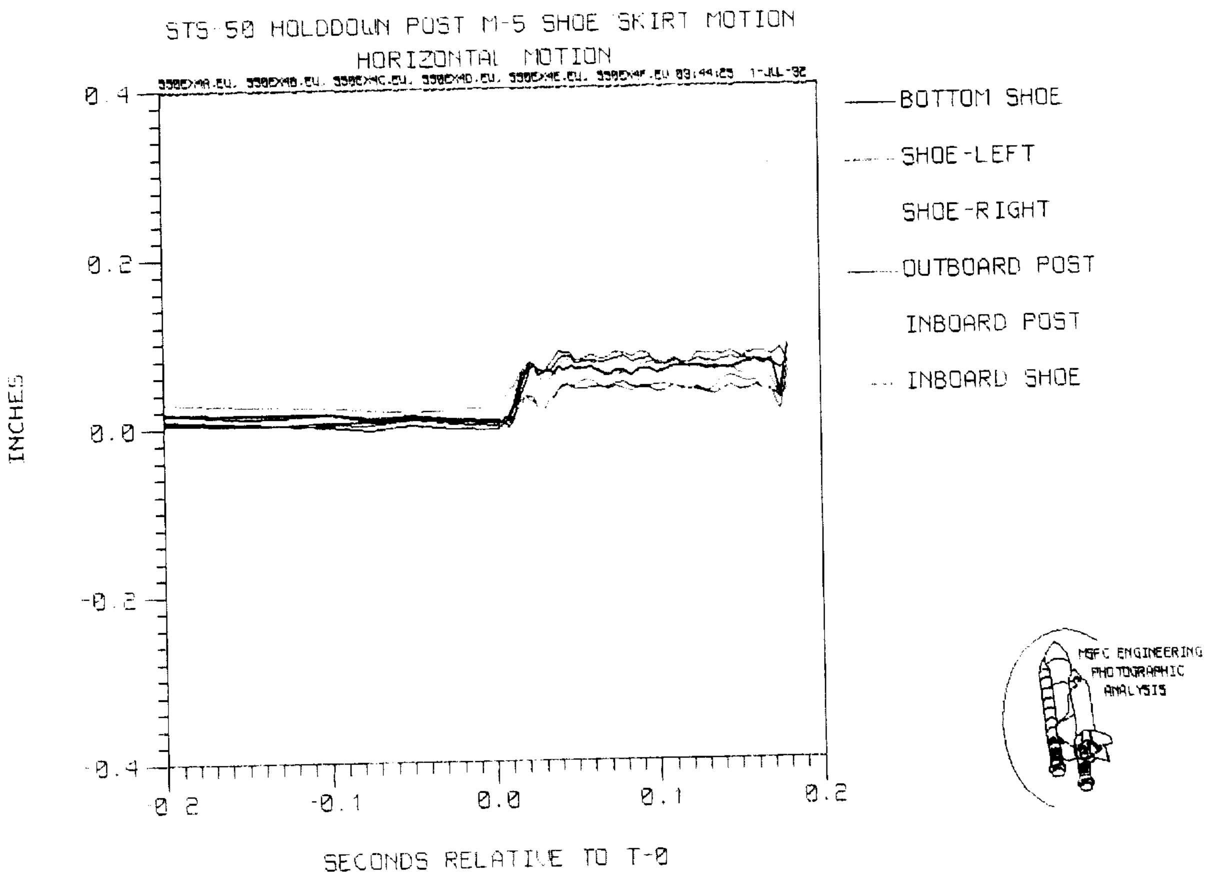


Figure 17

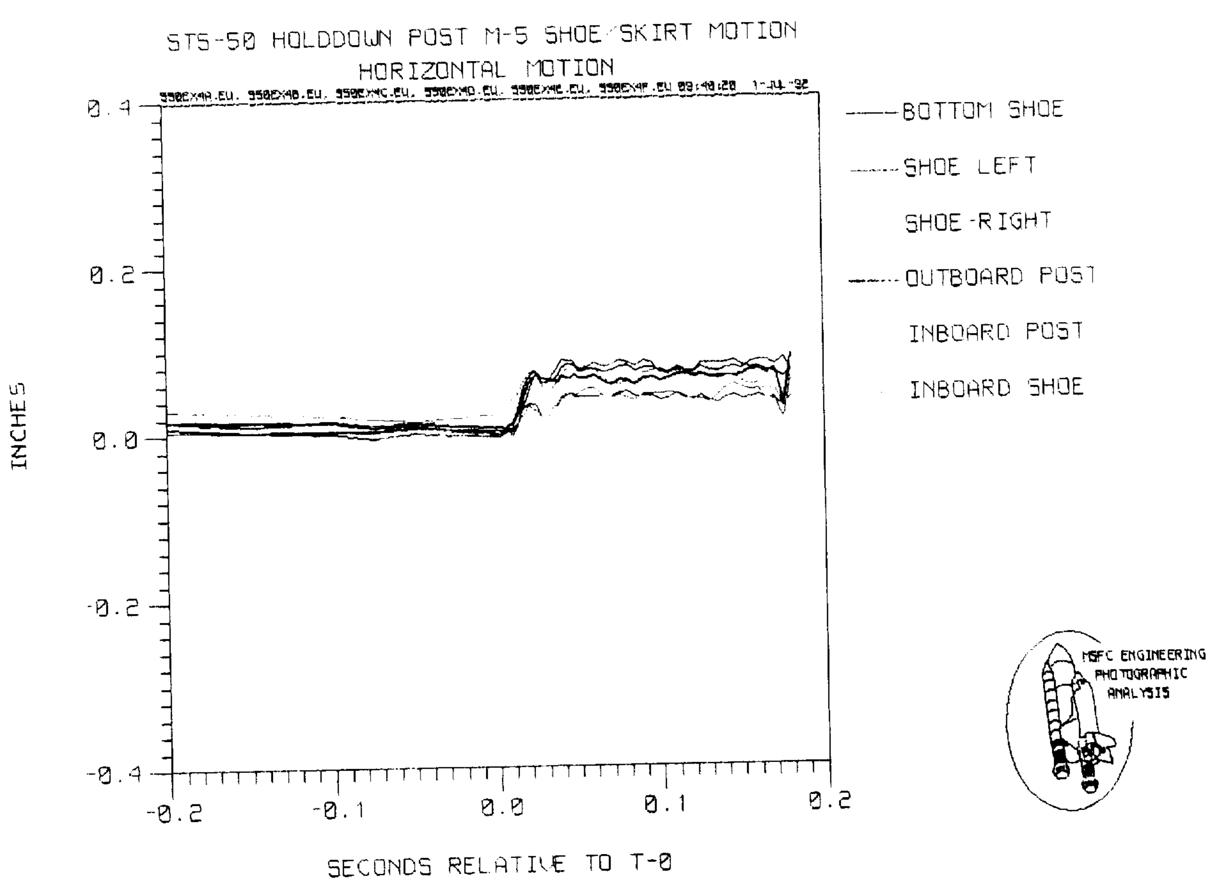


Figure 18

Appendix C. Rockwell Photographic Analysis Summary

Space Transportation Systems Division
Rockwell International Corporation
12214 Lakewood Boulevard
Downey, California 90241

Rockwell
International

August 19, 1992

In Reply Refer to 92MA3490

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: L. G. Williams (WA)

Contract NAS9-18500, System Integration, Transmittal of the Rockwell Engineering Photographic Analysis Report for the STS-50 Mission.

The System Integration Contractor hereby submits the Engineering Photographic Analysis Summary Report in accordance with the Space Shuttle Program Launch and Landing Photographic Engineering Evaluation Document (NSTS 08244).

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39A Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-50 launch conducted on June 25, 1992, at approximately 9:12 AM (PDT) from the Kennedy Space Center (KSC) and for the landing on July 9, 1992 at KSC (4:43 AM PDT).

Rockwell received launch films from 84 cameras (61 cine, 23 video) and landing films from 18 cameras (11 cine, 7 video) to support the STS-50 photographic evaluation effort. Two films, E-57 and E-77, were not available due to camera malfunctions.

All ground camera coverage for this mission including coverage on the MLP, FSS and tracking cameras were good. However, due to the accumulation of clouds, many of the tracking video and films reviewed were obstructed after the vehicle went through the cloud cover. This hampered analysis and possible detection of debris and/or anomalies.

Overall, the films showed STS-50 to be a clean flight. Several pieces of ice from the ET/ORB umbilicals were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver. No vapor was observed in the vicinity of the rudder/speed brake at liftoff. Charring of the ET aft dome and recirculation were not visible due to heavy cloud cover. Booster Separation Motor (BSM) firing and SRB separation appeared normal but could only be verified by one camera due to the cloud cover.

(Packing Sheet No. DM92-17888)

A disturbance in the lateral acceleration strip chart data at liftoff led Rockwell Engineers (Ascent Separation Systems) to suspect there had been a bolt hang-up on one of the SRB holddown support posts. This assumption was confirmed when films E-7 and E-10 were reviewed which clearly showed the post M-4 bolt to hang-up at liftoff. The bolt also deflected during liftoff until the aft skirt foot rose sufficiently to release it, causing the bolt to spring back to its original vertical position.

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Mission Elapsed Time (MET), as is normal. All blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH2 vent line carrier dropped normally and latched securely with no rebound. No anomalies were identified with the ET/ORB LH2 umbilical hydrogen dispersal system hardware.

STS-50 was the eigth flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up. Significant events that were seen include a bolt hang-up at holddown post M-4 of the right SRB at liftoff and a dark piece of flexible debris which originated from the right SRB flame duct and moved north away from the vehicle. These events and other events noted by the Rockwell film/video users during the review and analysis of the STS-50 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. A hangup of the holddown post M-4 holddown bolt on the SRB was seen at liftoff on cameras E-7 and E-10. Rockwell/Downey engineers had previously reported a disturbance in the lateral acceleration strip chart data at liftoff which led them to expect a possible holddown post bolt hangup. This event was clearly seen in the photographic review as the M-4 holddown bolt rose a significant amount during liftoff before breaking away from the SRB and springing back into position. No further analysis is planned.

2. On Camera E-7 a large piece of EPON shim material debounded from the holddown post M-4 aft skirt foot and fell into the flame duct during liftoff. This is probably caused by the M-4 bolt hangup. No further analysis is planned.

3. Orange vapor (possibly free burning hydrogen) was seen below the SSME's just prior to SSME ignition on cameras E-3, E-5, E-15, E-17, E-18, E-19, E-20, E-23, E-62, E-63, E-76 and beneath the body flap (moving north) on camera's OTV-063, OTV-070, and E-30. This vapor appears to be similar to the vapor noted on previous missions. It is not an issue and no follow-up action is planned.

4. Flexing (an up and down motion) was noted in the base heat shield in the centerline area between the SSME cluster during the early stage of SSME ignition. Base heat shield movement has occurred on previous missions and no follow-up action is planned.

5. On cameras E1, E4 & E15 a large piece of flexible debris originated from the RSRB flame trench shortly after SRB ignition. Does not appear to strike vehicle. No further analysis planned.

6. On camera E-18, Two pieces of debris (origin unknown) fall aft from above the left inboard elevon prior to liftoff. Does not appear to strike vehicle.

7. Orange flares and flashes seen in the SSME plumes (E2, E3, E52, E213, E222, E223). These observations are seen frequently and are understood to be burning of propellant impurities including RCS paper covers. No follow-up action is planned.

8. During the screening of the 16mm and 35mm umbilical well camera films an apparent rectangular shaped divot was seen on the LH2/intertank flange at the base of the left leg of the forward ET/Orbiter attach bipod. The forward bipod is in the standup position. Several small divots or chipping of the TPS was seen near the LO2 feed line, LO2 umbilical and the forward ET/Orbiter attach. Blow-ups of the ET 16mm & 35mm film is underway and analysis is in progress.

9. The following events have been reported on previous missions and observed on STS-50. These are not of major concern, but are documented here for information only:
    - Ice debris falling from the ET/Orbiter Umbilical disconnect area.
    - Debris (Pad, insta-foam, water trough) in the holddown post areas and MLP.
    - Butcher paper falling from the RCS.
    - Recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation.
    - Slight TPS erosion on the base heat shield during SSME start-up.
    - Shock waves visible on the pad at SSME startup.
    - Debris pieces in the SSME/SRB plumes.
    - Condensation around the SLV after the roll maneuver.
    - ET aft dome outgassing and charring.

10. Cameras E33 and E41 - OMRSD File IX Vol. 5, Requirement No. DV08P.010 requires an analysis of launch pad film data to verify that the initial ascent clearance separation between the left SRB outer mold line and the falling ET vent umbilical structure does not violate the acceptable margin of safety.

    A qualitative assessment has been conducted and positive clearances between the left SRB and the ET vent umbilical have been verified. The films showed nominal launch pad hardware performance, and no anomalies were observed for the SRB body trajectory.

11. Cameras E7-16 and E27-E28 - OMRSD File IX Vol. 5, Requirement No. DV08P.020 requires an analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.

    A qualitative assessment of the launch films has been completed. No anomalies were observed for the SRM nozzle trajectory and positive clearances between the SRB nozzles and the holddown posts were verified.

12. The landing of STS-50 occurred on runway 33 at the KSC Shuttle landing facility. Good video and film coverage of the drag chute deploy was obtained. The drag parachute system performed as expected. All sequenced events occurred as planned and no hardware anomalies were observed.

    Analysis continues in the areas of compartment door trajectory, reeled main chute operation, and riser position relative to the Orbiter stinger. The results of this analysis will be used to validate models against actual flight data, and to allow accurate predictions for future flights.

This letter is of particular interest to W. J. Gaylor (VF2) and J. M. Stearns (WE3) at JSC. The Integration Contractor contacts are R. Ramon at (310) 922-3679 or C. I. Miyashiro at (310) 922-0214.

ROCKWELL INTERNATIONAL
Space Systems Division

J. A. Wolfelt
Chief Engineer
System Integration

RR:sb

cc: L.W. Bethers, BC5, NASA/Downey, Ca
R. K. Gish, BC4, NASA/JSC, Houston, Tx
W. J. Gaylor, VF2, NASA/JSC, Houston, Tx
J. M. Stearns, WE3, NASA/JSC, Houston, Tx
D. Pitts, SN15, NASA/JSC, Houston, Tx
[redacted]
B. Hoover, BICO-1, NASA/KSC, Kennedy Space Center, Fl
C. Dailey, ESC/C90, JSC/Lockheed, Houston,Tx
T. Rieckhoff, EP55, NASA/MSFC, Huntsville, Al
Addressee

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
Debris/Ice/TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-50	August 1992
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Gregory N. Katnik Scott A. Higginbotham J. Bradley Davis	10. Work Unit No.
9. Performing Organization Name and Address	11. Contract or Grant No.
NASA External Tank Mechanical Systems Division Mail Code: TV-MSD-22 Kennedy Space Center, Florida 32899	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and integrated photographic analysis was conducted for Shuttle Mission STS-50. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and integrated photographic analysis of Shuttle Mission STS-50, and the resulting effect on the Space Shuttle Program.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
STS-50 Ice Frost Debris Thermal Protection System (TPS) Photographic Analysis	Publicly Available Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified		

NASA FORM 1626 OCT 86

KSC DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS REPORT DISTRIBUTION LIST 6/92

NASA - KSC

MK/B. Shaw
TV-PEO-2/P. Weber
TV-MSD-1/C. Stevenson
TV-MSD-2/L. Bolton
TV-MSD-22/G. Katnik (9)
TE-CID-2/C. Brown
TE-CID-21A/N. Pope
RO/R. E. Reyes

GK-5/Z. H. Byrns
SK/F. Huneidi
ZK-88/K. J. Mayer
LSO-178/H. L. Lamberth
LSO-437/J. Cawby
USBI-LSS/L. Clark

NASA - JSC

VA/D. Germany
WE3/R. W. Hautamaki
WE3/G. I. Good
ES3/C. Ortiz
SN3/E. Christiansen
SN5/D. E. Pitts

Johnson Space Center
Houston, Texas 77058

NASA - MSFC

ED35/D. Andrews
EE31/M. A. Pessin
EP55/T. J. Rieckhoff
SA32/J. G. Cavalaris
SA31/G. C. Ladner

Marshall Space Flight Center
Huntsville, AL 35812

Rockwell - Downey

AC07/J. McClymonds
FA44/R. Ramon

Rockwell International
12214 Lakewood Blvd
Downey, CA 90241

Martin Marietta

Dept. 3571/S. Copsey
Dept. 3570/C. Gray

13800 Old Gentilly Road
New Orleans, Louisiana 70129
P. O. Box 29304
New Orleans, Louisiana 70189

KSC DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS REPORT DISTRIBUTION LIST 6/92

NASA - KSC

MK/B. Shaw
TV-PEO-2/P. Weber
TV-MSD-1/C. Stevenson
TV-MSD-2/L. Bolton
TV-MSD-22/G. Katnik (9)
TE-CID-2/C. Brown
TE-CID-21A/N. Pope
RO/R. E. Reyes

GK-5/Z. H. Byrns
SK/F. Huneidi
ZK-88/K. J. Mayer
LSO-178/H. L. Lamberth
LSO-437/J. Cawby
USBI-LSS/L. Clark

NASA - JSC

VA/D. Germany
WE3/R. W. Hautamaki
WE3/G. I. Good
ES3/C. Ortiz
SN3/E. Christiansen
SN5/D. E. Pitts

Johnson Space Center
Houston, Texas 77058

NASA - MSFC

ED35/D. Andrews
EE31/M. A. Pessin
EP55/T. J. Rieckhoff
SA32/J. G. Cavalaris
SA31/G. C. Ladner

Marshall Space Flight Center
Huntsville, AL 35812

Rockwell - Downey

AC07/J. McClymonds
FA44/R. Ramon

Rockwell International
12214 Lakewood Blvd
Downey, CA 90241

Martin Marietta
Road

Dept. 3571/S. Copsey
Dept. 3570/C. Gray

13800 Old Gentilly

New Orleans, Louisiana 70129
P. O. Box 29304
New Orleans, Louisiana 70189